CODED VISUALIZATION: THE RHETORIC AND AESTHETICS OF DATA-BASED CULTURAL INTERFACE

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CODED VISUALIZATION: THE RHETORIC AND AESTHETICS OF DATA-BASED CULTURAL INTERFACE

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SUMMARY

In this dissertation, I present my research on the rhetoric and aesthetics of data visualization. To be specific, I investigate the influences of computation on the aesthetics and rhetoric of visualization through design research methods. My design research includes the construction of theoretical knowledge and research through practice.

First, the theory portion aims at building knowledge. For the rhetoric chapter, I develop a well-known definition of rhetoric, “art of persuasion” to discuss visualization specifically. The new rhetorical chances driven by computational technologies include users’ participation in creating data, experimental forms by digital production, procedural rhetoric, and off-site engagement. For the aesthetic chapter, I define the three perspectives of viewing the aesthetics of data visualization—look-and-feel linking beauty and utility, aesthetic communication for trustworthiness, and situated aesthetics. I also articulate the influence of computation on aesthetics covering encyclopedic cultural contents, remediated variable forms for modular data, aesthetics of pre-designed form, interaction bridging functionality and storytelling, platform for secondary data exploitation, and direct visualization for cultural visual media.

I synthesize the two aspects of visualization theories into a new concept of visualization, *coded visualization*. Containing the two lexical meanings of code—the computational process and the semiotic function, I define coded visualization as a data-based and cultural interface. The visual form of this interface is an aesthetic space where messages are coded through a computational process that is interpreted using cultural references. Based on this definition, I suggest a series of criteria that can be applied to the

design of coded visualization. In line with the process of visualization design, the criteria include participatory and mash-up cultural data, disagreement and conflict in contents, cultural references into computational forms, interaction for narratives and provocation, and proximate to current a civic event.

For the design practice, I emulate the critical attitudes of designers, and create visualizations and treat them as a central subject to demonstrate my theories. *The Political Grid Project* is a Twitter-based website in which tweets from two major candidates are presented and users can express their opinions by voting on these tweets. In a seamless way within the site, the collective data are presented through multiple pieces of visualization. I argue how the design criteria are applied and critique how the current design of the project can be improved to fully exemplify the concept of coded visualization.

Chapter 1

Introduction

Visualization—computer-supported mapping of data to visual forms—has become a ubiquitous medium realized in various styles and channels. A simplistic and traditional view to identify visualization is a technical toolset that supports accurate and efficient data analysis tasks. Beyond the role in science or engineering labs, visualization now works as a critical device to provide knowledge, generate discussions, stir viewers' emotion, and even envision the future.

Visualization has its roots in various fields, including computer science, graphic design, human-computer interaction, and journalism. For the study on visualization, which is an innately multi-disciplinary topic, it is necessary to understand how these related fields have approached visualization and on which aspects of visualization they have focused. Reviewing the approaches in the influencing domains, I find a problem space that brings a research question of this thesis.

In most cases, visualizations are created with computers and consumed on the Internet. Ironically, due to this inherently digital context of production and exhibition, there has been *a lack of discussion on the influence of computation on visualization* as it has played an important role in visual media. Exploring this problem is the core of this thesis as digital media research. While discussing how digital technology provides new affordances in creating, exhibiting and experiencing visualization. The focus of this dissertation is driven by an extended role of visualization. Beyond the traditional goal of visualization is "to amplify cognition" (Card, Mackinlay, & Shneiderman, 1999), the

presentational (Mackinlay, 2000) and storytelling (Segel & Heer, 2010) purposes have gained attentions from researchers. Considering the expanded role of visualization, I particularly focus on its *rhetoric* and *aesthetics*. In addition, these research topics *regarding visualization* are not adequately discussed in digital media studies, design research, and the other related fields a further study is necessary.

Digital rhetoric is an emerging topic among digital media scholars (e.g., Losh's Virtualpolitik (2009) and Bogost's persuasive games (2007)) and rhetoricians. In contrast, the conversation on the *rhetoric of visualization* has been addressed only recently by a small number of scholars. Similarly, the general theories for aesthetics of digital media have been advocated for in many different perspectives such as remediation (Bolter & Grusin, 2000), immersion and agency (Murray, 1997), and representation and navigation (Manovich, 2001). However, there are no established discussions and commonly accepted ideas of aesthetics related to data visualization.

The rhetoric of visualization is the mechanism that delivers the creator's intention and steers viewer discussion; aesthetics encompasses not only the visual impression of media but also the holistic experiences along with the computational process from the contents as data to the form of realization, and to contextualization of the use.

The two aspects of data visualization—rhetoric and aesthetics—are not separate topics, but reciprocally influential in the concept of computation and the core characteristics of digital media. For emphasis, I coined a new term, *coded visualization*, which encompasses the dual meanings of code—semiotic function and computational production. These two meanings link to rhetoric and aesthetics, respectively, and finally integrates the two concepts. Ultimately, I claim that coded visualization is a *cultural*

interface, as it not only functions as a technical device, but also provides the audience with a space where they can experience cultural artifacts.

As a way of investigating the rhetoric and aesthetics of visualization, the research methodology of this thesis is *design research*. Design research involves both knowledge construction through theoretical investigations and design practices and critiques. On one hand, it builds the knowledge of design process, design materials, artifacts and designers. On the other hand, it integrates the practices of design with critical attitudes. Design research provokes social and humanitarian issues and seeks solutions.

This dissertation is a work of both theory and practice. Against the background of the literature of new media theory, classical and visual rhetoric, aesthetic notions from HCI and interaction design, and graphic design history, I discuss the rhetoric and aesthetics of visualization. Then I argue how the aesthetic and rhetorical visualization is integrated within coded visualization and suggest its design considerations. In addition to theoretical approaches, *research through design* is another promising way to demonstrate the value of visualization; by applying the design criteria to a visualization-centered system, I can make an artifact, find the challenges in designing coded visualization, and finally suggest how to improve the system to satisfy the criteria.

This study on the rhetoric and aesthetics of visualization through design research will contribute to both digital media studies (also a narrower field of digital humanities) and design research (as an alternative approach to HCI). Scholars in the field of digital media have researched the new rhetoric rising in the use of new media in general or video games in particular. However, visualization has never been a sole focus for the digital media researchers. Moreover, digital humanities deals with visualization as a novel way

of representing research materials but do not necessarily concentrate on the aesthetics of visualization itself. Similarly in design research, interaction designers and HCI researchers recognize the potential of visualization in the implementation of data-intensified interactive systems. Despite a growing interest in the community, there are not sufficiently serious discussions on what, how, and why we design with critical attitudes when data and its representation are a core concern. My research is significant because it aims at overcoming the currently narrow definitions and research focus of visualization.

This thesis is organized as follows:

In this chapter, I provide an overview of the research including thesis statements, approaches to solve the current problems, and the significance of this research.

Chapter 2 identifies the problem spaces in detail that are explored throughout the dissertation. First, I show several examples of data visualization and describe their data, forms, and purposes. Second, I introduce how these examples are understood through the current approaches in the related fields that partly ground subsequent research efforts. Third, through the articulation of the deficiency from the existing approaches in the visualization research and practices, I propose research questions. Last, I explain why choose design research as a methodology by situating visualization as a subject of design research and media studies.

Chapter 3 and 4 are the theoretical part of the thesis. I investigate the rhetorical aspects of visualization and the aesthetics respectively. Although I allot two chapters for the theories, this divide does not infer that the two entities are separate or chronological.

Chapter 3 is about the rhetoric of coded visualization. I consider visualization itself a channel for messages. First, I introduce closely related theories, visual rhetoric

and rhetoric in design. While discussing the rhetoric of non-digital visualizations, I connect visualization to modern graphic design from the 20th century and examine the tradition of printed visual media used for social impact. The core part of this chapter is the influence of digital technology on rhetoric. For this, I review the current perspectives on rhetoric in visualization research and digital rhetoric in general, from which I find the supportive theories and limitations. Throughout the visualization process, I discuss new rhetorical opportunities of the digital artifact, including the new roles of and relationships between authors and readers.

Chapter 4 is the other part of coded visualization—aesthetics. First, I explain what I mean by "aesthetics" by analyzing and synthesizing what researchers in neighboring fields have said. Three aspects of the aesthetics that I induce are look-and-feel, aesthetic communication, and situated aesthetics. Beyond the visceral responses to the visual resemblance between computational visualization and modern graphic design, I investigate the tradition of look-and-feel of visualization relating to the principles of modern graphic design and their applications. Using the other two aspects (aesthetic communication and situated aesthetics), I discuss the influence of digital technology on the data and the following forms and examine some characteristics of the novel aesthetic phenomena.

In chapter 5, I integrate the previous two chapters and characterize what coded visualization means in my thesis and how it is different from previous definitions of visualization. I also claim how and why data visualization becomes a cultural interface. Last, I suggest design criteria for coded visualization along the expanded process of visualization.

Chapter 6 is reserved for discussion on design projects. The thesis project is called *The Political Grid Project*. It is a Twitter-based website where people can vote on presidential candidates' tweets and explore voting data through various visualizations. As another way to answer the greater research questions of the thesis, I apply the design criteria of coded visualization, and discuss the technology, design description and challenges. After the release of the site to the public, I critique how successfully this site exemplifies the design criteria and discuss how to improve the site as a coded visualization project. Through this practice (making and critiquing) of design research, I validate the theories that I discussed earlier and describe how coded visualization becomes a cultural interface and triggers social engagement through.

In the final chapter, I summarize the thesis and highlight the contribution to the fields of digital studies and design research.

Chapter 2

Identifying problem spaces

This chapter aims at stating problems, research questions, and research methodologies. I start with sketching the scene the thesis investigates so that readers review the current situation of visualization. For this, I present various examples of visual media that exploit visualization and outline current approaches from diverse fields to designing and researching visualization. I choose information visualization, graphic design, human-computer interaction, and data journalism to find problems because they are the disciplines that closely deal with visualization as well as interdisciplinary fields by themselves related to digital media studies. Drawing on the deficiencies in their approaches, I construct two research questions and suggest suitable research methodologies from design research. In this chapter, I clarify why I use design research for the research on visualization in particular, and digital media studies in general.

2.1. Sketching the landscape

Manovich (2002) uses visualization when referring to situations where quantified data, which by itself is not visual, is transformed into a visual representation. He later defines visualization with different formulation—"a remapping from other codes to a visual code" or "a mapping between discrete data and a visual representation"—for the same meaning (Manovich, 2010). In other words, *visualization is the process in which data in various forms gain visual properties that are new or different from the original*

form. Through visualization, not only numerical or discrete data, but also visual, textual, audible, and even mixed media can be represented and realized in visual ways.

Categorized in this definition of visualization, the examples in this section show diverse techniques for the representation of data that cover conventional line graphs and charts to abstract artwork. While much of the representation of data is crafted for display on a two-dimensional screen, some are realized in the form of installation art and even in architecture. The themes of the data in the examples also vary, ranging from environmental issues such as greenhouse gas emissions and electricity usage to political topics such as unemployment rates. Throughout this glimpse into a wide array of techniques and themes, this section attempts to present the manner in which one materializes and delivers the following key concepts of visualization: the data (content), the techniques for visual mapping in diverse contexts (form), and creators' intentions and the effects of the content on viewers (messages).

2.1.1. Digital media with embedded data

One illustration of data-based digital media is the documentary *film An Inconvenient Truth.* This film features former U.S. Vice President Al Gore, a well-known for using diagrams to illustrate his arguments. In this film, from 2006, he used a multitude of graphs and maps to depict scientific data in order to stress the impact of global warming, For example, he showed a severe increase in CO2 and temperatures during the past few years using line graphs that go "off the chart"—even going so far as pointing at the lines while standing on a forklift (Figure 1). By extending the graphs to projections of the future, he made the lines soar.

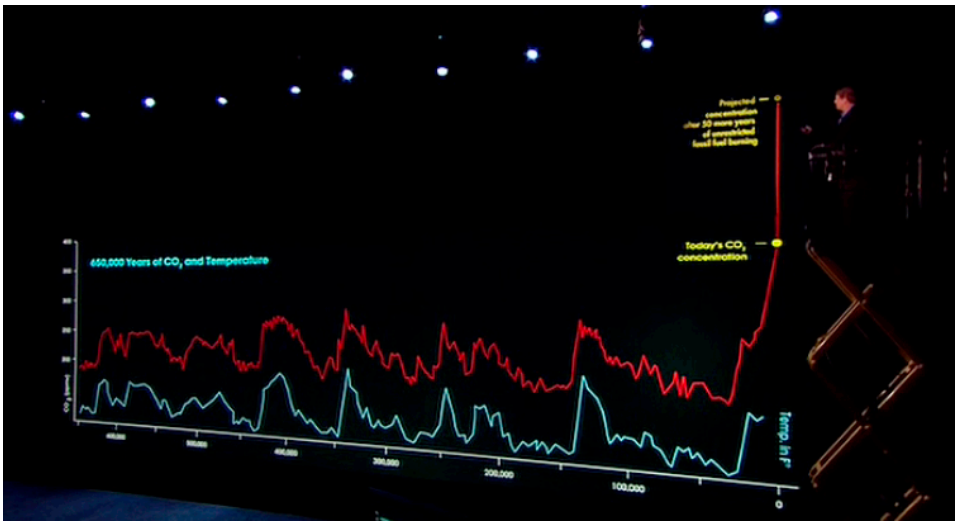

Figure 1. 650,000 years of CO_2 and temperature

Another example of a visual medium illustrating political data is the bar graph *Road to Recovery* (Figure 2), which the Democratic National Committee released to the public in February 2010 via its website. The graph shows job loss trends during the previous two years. It contrasts the performance of the Obama Administration to that of his predecessor through a simple bar graph that shows the representative colors of the two parties. At first sight, the bar graph seems to show a dramatically positive change in unemployment since Obama took office. In this way, the intended message of the Democratic Party can be delivered without distortion to audiences who are not armed with skills to critically interpret the data and the graphs.

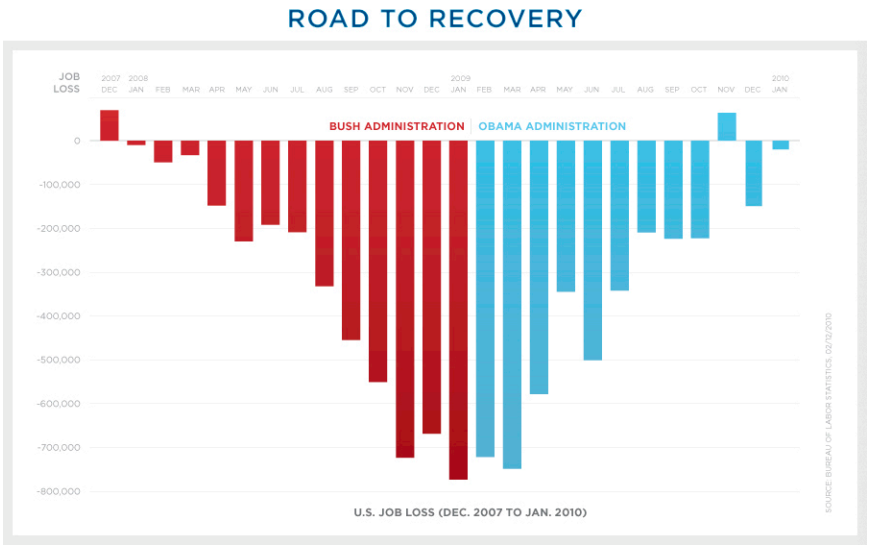

Figure 2. *Road to Recovery* (http://my.barackobama.com/page/content/recoveryanniversary)

One different style of digital media (Figure 3) is *What is a black balloon?*, a series of motion graphic advertisements for a statewide environmental campaign in Victoria, Australia. It represents greenhouse gas emissions from domestic environments such as kitchens, laundry rooms, and dining rooms. In the video clip, home appliances are releasing black balloons, each representing 50g of greenhouse gas, into the air. Each appliance releases balloons until the ceiling of the house is completely covered by the balloons without the occupants of the house noticing them. This advertisement illustrates people's ignorance of the potential threat to their environment.

Figure 3. *What is a Black Balloon?* (http://www.saveenergy.vic.gov.au/blackballoons.aspx)

An even more abstract representation of number is the series of photographic art called *Running the Numbers: An American Self-portrait* by Chris Jordan. One of these works is *Plastic Cups* (Figure 4), in which he depicts one million plastic cups, the exact

number of cups used on flights in the United States every six hours. Representing multivariate data is the boundary of Information Visualization (IinfoVis), so this image may not be a visualization work according to InfoVis scientists' standard. However, I consider this work visualization in a broader sense and focus on its unique form. If viewers look at the image from a distance, it appears as an abstract drawing of pipes, but upon closer inspection, they can see that the image is composed of a multitude of disposable plastic cups.

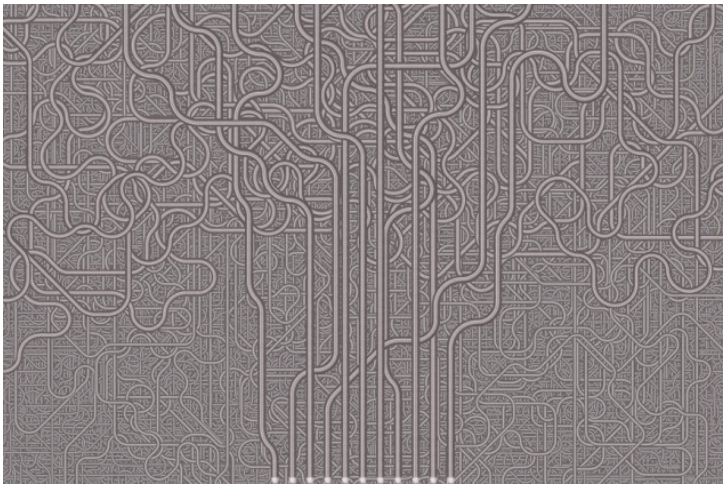

Figure 4. *Plastic Cups* (http://www.chrisjordan.com/gallery/rtn/-plastic-cups)

The exhibition channels for the above examples all differ: a PowerPoint-style presentation in a big auditorium, an image file on a website, an internet video clip, and a canvas mounted on a wall in an art gallery, respectively. However, all of the creators harnessed numerical data as a the source of the contents: the temporal trends of environmental change data, the unemployment rate, carbon dioxide emissions from home appliances, and a specific quantity of a single object.

Another shared (and somewhat obvious) trait of these data-based media is that the creators used digital technology when they produced the media. For example, the artist of *Plastic Cup* (Figure 4) indicates that he took a picture of a much smaller number of cups,

then duplicated and manipulated the original photography to obtain the final gigantic image (personal communication, April 4, 2011). In theory, it is possible to gather millions of plastic cups and to arrange them as we see in Figure 4. However, photo-editing technology can immensely reduce the amount of labor and time need for production.

The next group of work I will discuss (from Figure 5 to Figure 7) exploits digital technology more explicitly. In these examples, users interact with images; they navigate on the screen and so that their input modifies the images. Some are available through a network, which enables users to access a more encyclopedic range of data than are exhibited through static media. Others allow users to provide data and participate in the real-time representation of the data.

Two examples are based on health-related data (Figure 5 and Figure 6). In addition, these are web-based applications and have interactive features that allow users to sort, filter, and highlight some values in an entire dataset. Seemingly a computational version of Nightingale's famous coxcomb diagram (http://www.scottlan.edu/lriddle/women/nightpiechart.htm), *The Cost of Getting Sick* by GE (Figure 5) shows the medical expenses for the most common diseases among Americans divided by age groups. While sliding the bar for age, a user can observe the changing cost to treat each disease.

Rosling's animated visualization (Figure 6) shows that the HIV virus infection rate has increased to 50% a few African countries over the past three decades, while the percentage of the infected among the total world population has remained in the single digits.

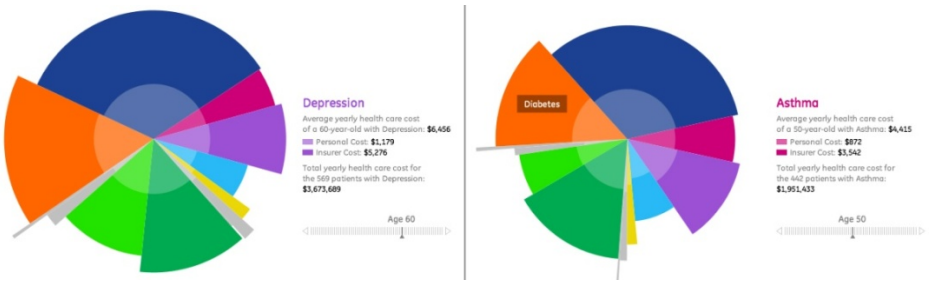

Figure 5. *The Cost of Getting Sick* (http://visualization.geblogs.com/visualization/health_costs/)

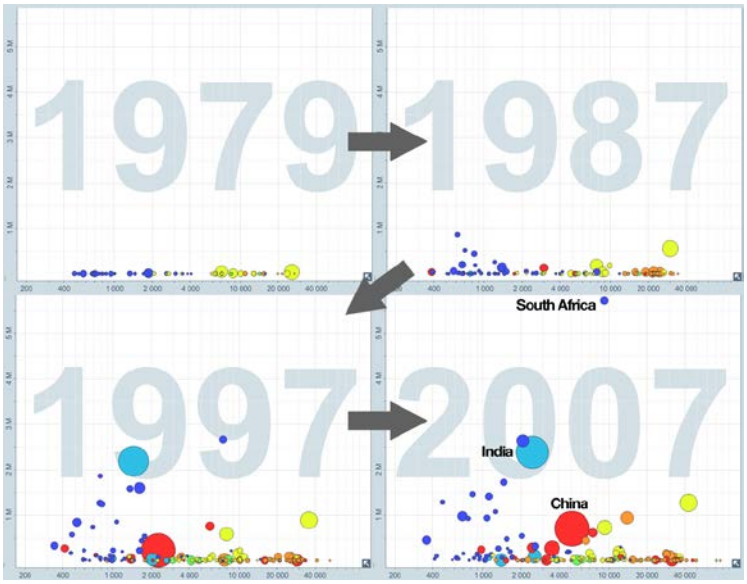

Figure 6. People with HIV (http://www.gapminder.org/videos/ted-talk-2009-hans-rosling-hiv-facts/)

Another data representation that illustrates interaction between the users and the media is a website *VoteEasy* that exploits visualization as a core part of visual interface (Figure 7). It guides a user from an introductory screen selecting a home state to the final one that shows detailed information about the selected candidates in a linear and procedural way. The user selects up to twelve issues and provides her or his personal opinion. Each issue is described as a question—for example, "Do you support the elimination of the federal estate tax?" Based on the answers to the questions, the system computes the similarity to candidates. The more questions a user answers, the more accurate results provided are.

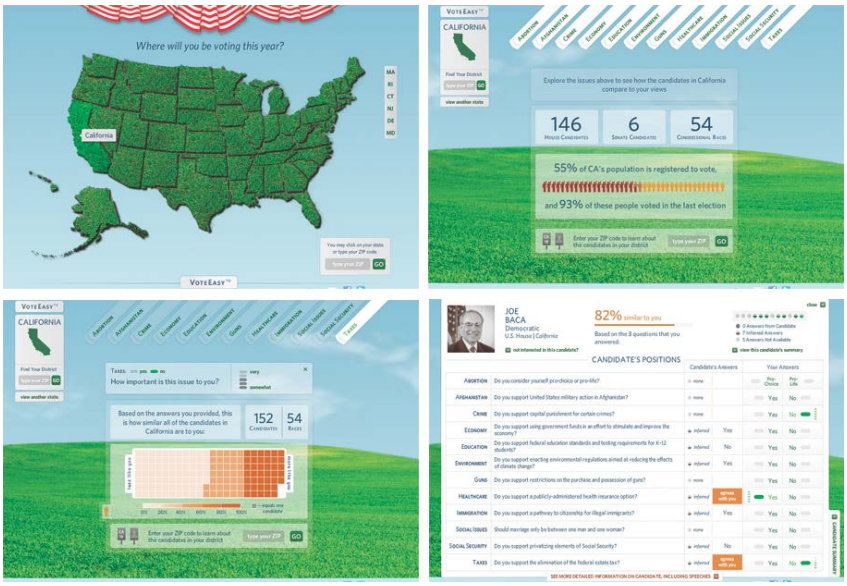

Figure 7. *VoteEasy* (http://www.votesmart.org/voteeasy/)

The following examples, unlike the previous ones, are not two-dimensional. Instead, they are physical installations in which designers represent data in abstract ways and interactive forms.

Living Light (Figure 8) is a permanent outdoor pavilion installed in Seoul, Korea. The shape of the building façade abstracts the administrative divisions of Seoul, and each part glows and blinks in response to the air quality data of that division. This installation also reacts to the public via text messaging. When a visitor sends a text message containing a zip code to a special number connected to the pavilion, the corresponding part of the pavilion blinks. At the same time, the system sends a message back to the visitor with more information about the air quality of that division.

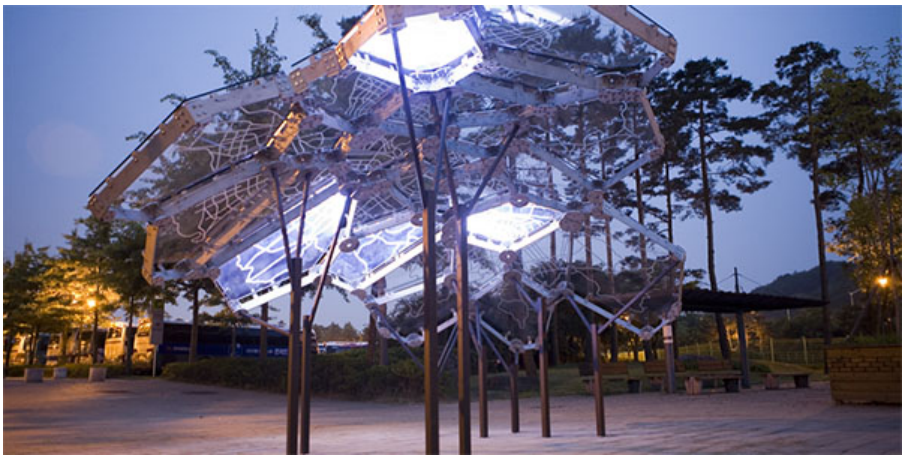

Figure 8. *Living Light* (http://www.livinglightseoul.net/)

Nauge Vert (Figure 9), or "green cloud" in French, is a city-scale light installation that was first realized in Helsinki in 2008. A laser—pointed towards the emissions from the chimney of a coal-burning power plant—draws a neon-green sign in the sky. Its outline is animated based on the real time energy consumption of the city residents. The size of the green cloud grows bigger as local residents consume less energy.

Figure 9. *Nuage Vert* (http://www.pixelache.ac/vihreapilvi)

2.1.2. Messages embedded in the data-based digital media

All the examples in this section have social and political messages to some extent, no matter where the data sources come from or in what forms they are presented. Some

messages seem explicit, providing viewers with unknown facts and knowledge through pragmatic visualization, while others raise awareness indirectly of hidden problems through abstract visualizations. In both cases, the creators ultimately urge viewers to become more enlightened or even to take action. How these visualizations influence the viewers' cognitions and emotions is an immense question that has not yet been thoroughly explored. Here, I discuss a few possibilities for rhetorical strategies used to convey messages in the examples above.

In *An Inconvenient Truth,* Gore is considered to have succeeded in elevating political debate to general moral concerns, coupling classical rhetoric through speech with visual, graph-based rhetoric. In Figure 1, the line graphs of CO2 emission soar to become almost a vertical line, which give a vivid sensation that "we are in serious danger." By creating an emotional response, this visualization strengthens his argument, persuading audiences to take action by reducing energy consumption and waste in order to overcome the crisis.

Another example, *What is black balloon?* (Figure 4) attempts to deliver an obvious but possibly unrecognized fact: Using less energy means emitting less greenhouse gas—the type of gases that most impact climate change. While they watch this advertisement, viewers are not expected to count the exact number of balloons and calculate the total emission of greenhouse gas. Instead, they may respond more viscerally, by panicking or experiencing a sort of emotional paralysis while witnessing the abstracted and aestheticized statistics.

Similar responses can be expected from viewers when they see other unconventional visualizations of politically charged data. The artist of *Plastic Cups*

(Figure 5) clarified his belief: “My hope is that images representing these quantities might have a different effect than the raw numbers alone, such as we find daily in articles and books… I hope to raise some questions about the roles and responsibilities we each play as individuals in a collective that is increasingly enormous, incomprehensible, and overwhelming.”

Conventional diagrams and charts appear to be straightforward in delivering facts. At the same time, they can also engender a more personal understanding beyond simple information delivery. For example, *The Cost of Getting Sick* (Figure 6) does not only convey the objective statistics of medical costs but also offers a chance for reflection. Viewers can ask why costs, especially personal costs, increase as people get older, which is not a commonly accepted phenomenon in the countries with a universal healthcare system.

A website *VoteEasy* (Figure 11) aims at helping a user learn the political stance of house and senate candidates in their district in order to determine who best suits the user. Although citizens have access to a plethora of information, finding the right candidates requires a complex process of analysis and comparison. By supporting this difficult task through easy-to-answer questions, the system persuades a user to pay attention to what these candidates say about social and political issues. It further helps the user choose the candidates whose opinions he or she agrees with.

As an installation artwork at a park, *Living Light* (Figure 8) has a roof whose form breaks down the city of Seoul into twenty-seven sub-sections corresponding to the places where the government installed devices that sense air pollution. The artists believe this division implies an authoritarian structure in the city. In other words, besides the contents

of the visualization, the stage where visualization is projected contains hidden social messages of power hierarchy.

Nuage Vert (Figure 13) is an example that invites the public in a more personal way. Working with local activists and journalists, the artists advertised their exhibition and asked the citizens to be part of an "unplug event." During the one-hour event, four thousand local residents reduced their energy consumption by 800 kVA, or the power generated by a windmill running for one hour. The artists described the contribution of their work as follows (Evans, 2008): "This is the first time that an invisible digital infrastructure measuring local electricity consumption had been made public and visible. (…) The results of the unplug event—realized on a tiny budget and with limited resources—points to the future possibilities for urban planners to make complex calculations and networked information available as public forms. Giving form to the relationships between institutions and those that consume their services could lead to the creation of a new type of citizenship and the transformation of a city."

The examples in this section present the wide spectrum of visualization in terms of the purposes of creation, the implemented forms, and the temporal and locational context of exhibition. In other words, I showed the diverse occasions of the realization of aesthetics and rhetoric of contemporary computational visualization. Throughout the thesis, I build arguments to theorize visualization as a genre of digital media that include the examples above. In addition, this thesis as a design research aims at producing knowledge for designing such visualizations.

2.2. Current approaches

The various examples earlier introduced certainly cross borders of several disciplines and realized with multifaceted attitudes. In shaping the contents and expressing the messages of visualization, creators are expected to be versatile; they are required to have the analytic ability of scientists for understanding and interpreting data and the aesthetic sense of designers for presenting the data in visually and interactively pleasing forms. Moreover, to influence wider audiences, creators need the thought-provoking perspectives of artists and even the care for society and humanity of philanthropists.

In exploring such diverse aspects of visualization, many established disciplines have contributed to the body of visualization research. Some of them are information visualization in computer science, graphic design, human-computer interaction research, and data journalism. To formulate the problematic spaces of my thesis, it is necessary to investigate how these adjacent fields approach to the research of the related issues to coded visualization.

2.2.1. Information Visualization for presentational purposes

One of the most relevant disciplines that help to understand coded visualization would be Information Visualization (InfoVis). Originating within computer science, InfoVis has been regarded largely as an realm of, by, and for scientists and engineers. It principally functioned as a technical tool to support knowledge construction as well as fast and accurate data analysis. According to Card, Mackinlay, and Shneiderman (1999, p. 6), one of the goals of visualization is “to amplify cognition.” Fry (2004, p. 33) extends this definition, saying “the ability of InfoVis is to help us ‘see’ things not previously

understood in abstract data," and claiming "our limited mental capacity is aided by methods for 'externalizing' cognition." InfoVis researchers have continuously suggested new visual techniques, emphasizing mainly utilitarian aspects (e.g., the capacity of represented data and the usability of the system).

In the past decade, however, there have been new research directions suggested for non-analytical uses such as storytelling and presentation over exploration (Mackinlay, 2000). The importance of these communicative and illustrative aspects has been illustrated through concepts of such as "social visualization" in which researchers seek to convey social information in non-scientific forms (Donath, Karahalios, & Viégas, 1999), or "casual information visualization" that is used by non-expert users to depict personally meaningful information (Pousman, Stasko, & Mateas, 2007). More recently, "narrative visualization," an emerging topic among InfoVis scientists, focuses on the potential of storytelling through InfoVis (Segel & Heer, 2010).

In earlier days, InfoVis scientists' main concerns were the coverage of data and legibility. They suggested various visualization techniques and algorithms while not paying sufficient attention to the visual appeal because they thought it was not the first priority for analytical purposes. Thus it was not surprising that the early InfoVis prototypes usually adopt primary screen colors—red, green, and blue and aliased lines.

In recent years, though, many novel visualization techniques are both visually appealing as well as the technically efficient. One example is a visualization of adjacency relationships in hierarchical data presented in a unique form, different from common visualization techniques such as a Treemap (Holten, 2006). Hierarchical Edge Bundles use an algorithm of organic curves that represent hierarchy and relationship through

connecting points on the circumference of a circle (Figure 10). This visualization technique is more unique and innovative than the banal geometric lines or curves, supporting better visual perception. I also argue this uncommon look may result in better visual attractiveness when compared to traditional computer graphics. Another interesting example is a novel technique to stack graphs that do not start with flat x-axis (Byron & Wattenberg, 2008) (Figure 11). Further, each graph does not have vertices at discrete temporal points, but instead, the results are streamlined to great effect.

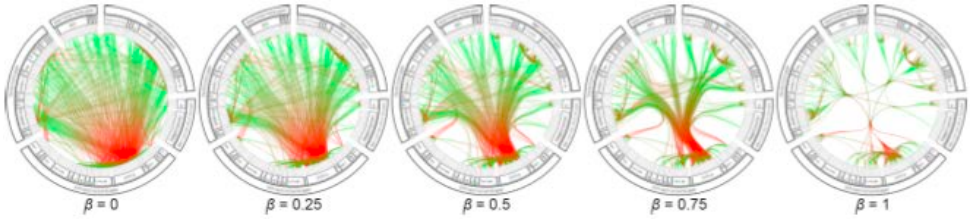

Figure 10. Hierarchical Edge Bundles

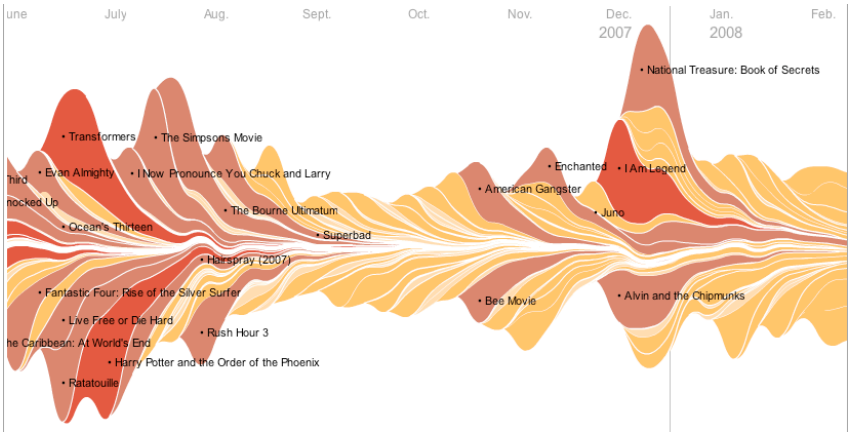

Figure 11. The Ebb and Flow of Movies: Box Office Receipts 1986-2008 (http://www.nytimes.com/interactive/2008/02/23/movies/20080223_REVENUE_GRAPHIC.html)

2.2.2. Graphic design with unrefined data

Information design is a mature genre in visual communication design. Although information design and visualization are often interchangeably used in non-processional or non-academic contents, they should be distinguished. According to Manovich (2010), information design starts with data that already has a clear structure, and the goal is to

express this structure visually. In addition, information design creates a way of visual presentation that is already reduced to some extent. This means that the raw data has already evolved to become information that has an inherent structure. For example, the diagrams of public transit routes in a city represent the structural information derived from multiple datasets, such as metro or bus lines, station names, as well as the arrival and departure times for each line and station.

In recent years, many (information or interaction) designers have exploited crude data as resources. In conjunction with the expanding boundaries of InfoVis to include a wider range of audiences, graphic designers' active use of data has made visualization more accessible to the public. These ubiquitously seen artifacts employing visualization techniques by graphic designers are now widely called *information graphics,* or, more commonly, *infographics*. Figure 12 is the famous infographic work produced by graphic designer Nicholas Felton, who since 2006 has published visualization-based annual reports of his own life. In his visualizations, he depicts detailed statistics of personal data, such as countries visited, books read, and music played.

On many occasions, infographics exist as a single static image that draws on smaller datasets than scientific InfoVis. They also use more refined, mined, and meaningful aspects of these data, which is in fact a concern of information design. These infographic resources could be positioned somewhere between numerical crude data and refined information. Although such infographic works might be called visualization in a strict sense, this diversity of abstraction levels has allowed graphic designers to use their skills to not only repurpose conventional diagrams but also to create unique visual norms.

The Future of Food (2008) (Figure 13) is an infographic about the quantity of dairy products consumed in the U.S. It can be considered information design rather than data visualization due to the large portion of photographic elements. The photographs of a cow and a milk jar are used for visual impact, as opposed to the objective information delivered through the textual elements. In contrast to the big images, the elements of data visualization as a semi-3D bar are only a small portion of the entire image. From the perspective of strictly reviewed InfoVis advocating minimalism, the 3D shape only distorts the pure presentation of data. However, it arguably has aesthetic benefits and draws viewers' attention by exhibiting a strong contrast against the photographs of real objects.

Admittedly, the personal taste of designers may not incline toward the austere minimalist principles, to the point that their work could be criticized as "chartjunk" (Tufte, 1990, p. 34). Despite the risk of making this chartjunk, these flexible approaches can bring in atypical visual languages while balancing the informative effects and aesthetic satisfaction with a great eye for typography, layout and colors. Recent experiments also indicate the positive role additional graphics perform in helping test subjects to remember the messages of the visualization in a longer term (Bateman et al. 2010).

Graphic designers' involvement has broadened not only the form but also the content of visualizations. They volunteer in design projects for the general public or initiate their own projects to express their political opinions or social responsibility. In recent years, graphic designers have reacted to social issues by designing visualizations in a timely manner. For example, shortly after the tragic earthquake in Haiti in 2010, a

design blog held an infographics design contest titled “Design for Haiti.” In the contest, they looked for visualizations that “call attention to an action (i.e., help or donate)” and “create better understanding of the situation” (“Project: Create an Infographic,” 2010). The submitted work ranges from representations of scientific data about the natural disaster to financial aid from other nations (http://www.designforhaiti.com).

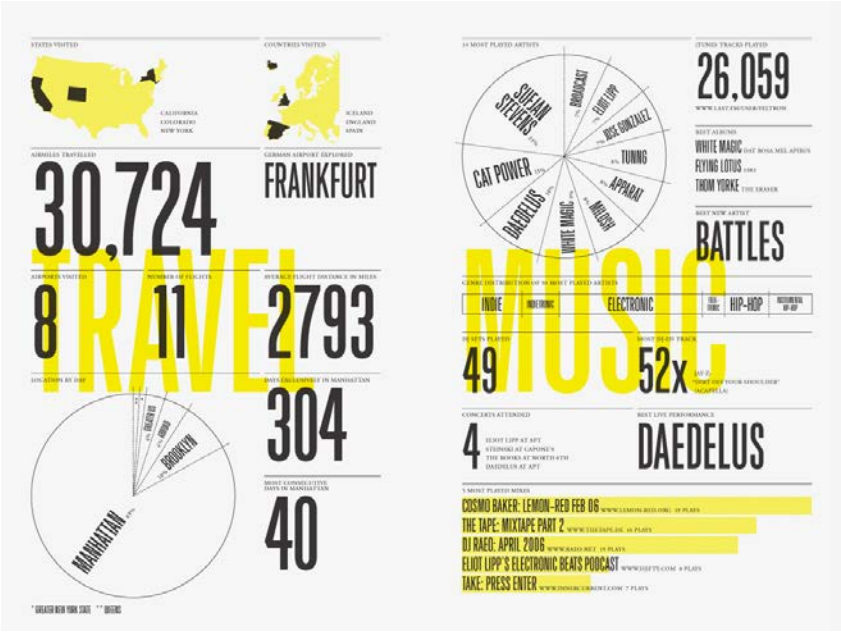

Figure 12. Infographics of personal data: 2006 annual report by Nicholas Felton. (http://feltron.com)

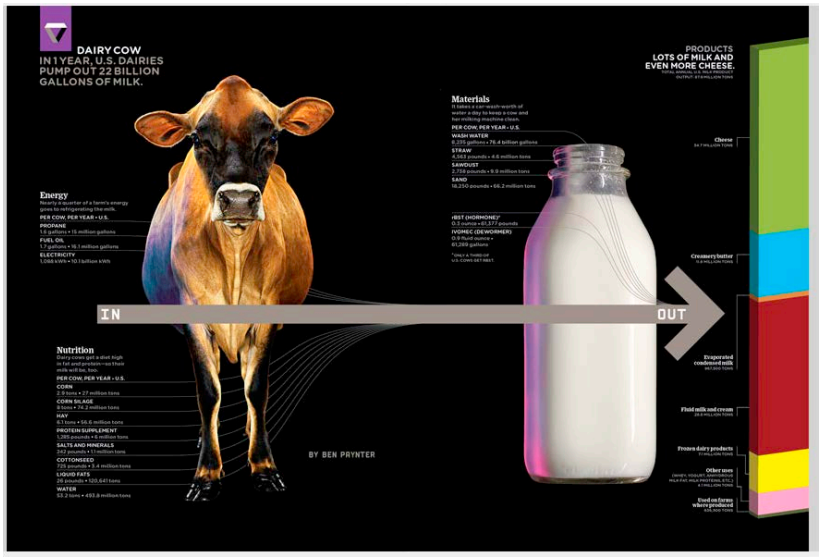

Figure 13. *The Future of Food* (“The Future of Food,” 2008)

2.2.3. Human-centered computing research for persuasion

Beyond its focus on utility and cognition issues within productivity applications during the 80's and 90's, numerous Human-Computer Interaction (HCI) research projects are now concerned with the positive influences of HCI on society at large. Hochheiser and Lazer (2007) suggest four areas to which HCI can engage with societal issues: personal and community needs, business and organizational needs, governmental needs, and technological innovation. Under personal and community needs, they indicate accessibility issues for people with disabilities, universal usability, and HCI for children and older adults. They also argue that technological innovations trigger HCI research for social issues such as privacy, trust and credibility, and security.

As a particular interest in HCI, persuasive technology serves as a practical theory that can be adapted to designing digital. Fogg (2002) defines persuasive technology as interactive computing systems designed to change people's attitudes and behaviors. He suggests that digital technologies enable new ways of persuasion that traditional media could not have achieved; interactive systems have advantages over human persuaders because computers function as supportive tools, media of simulation, and social actors. Although Fogg's work has been influential in the development of so-called persuasive technology systems, it presents a rather surface treatment of persuasion and covers basically all possible interactive dialogues including online shopping websites. Thus, Fogg's theory is not specific to the domain of social and public benefit. However, with some theories from behavioral psychology, it provides a rationale in designing persuasive systems from the technological perspectives.

Researchers working on health management or sustainability issues, which are among the broad range of social issues that HCI can contribute to, believe in the power of computing in changing individuals and communities in positive ways. They develop interactive computing systems that support altering people's attitudes and behavior. As HCI research comes closer to everyday life, obtaining data in the end-user context is crucial for designing persuasive products and services. Researchers gather data through self-reporting methods or via sensing technology. For example, mobile phones allow a user to record her transportation means and time in transit manually (Froehlich et al. 2009). The inexpensive sensors embedded in phones detect the environmental data such as air quality and noise in a non-intrusive manner (Paulos, Honicky, & Hooker, 2008).

In the implication phase of application design, InfoVis techniques are actively employed for the effective visual representation of the gathered data. Final visualizations are often realized as familiar diagrams and function as part of screen-based user interfaces. Beyond the typical forms of graphical user interface, many HCI researchers and interaction designers develop ambient displays or information systems (Figure 14). For visualization, ambient displays can be suitable domains for persuasion. In my previous research, I designed Mac OS Dashboard widgets that visualize computer usage time, and concluded that ambient techniques mainly marked by their pervasiveness could encourage users to modify their behavior (Kim, Hong, & Magerko, 2010).

Figure 14. Power-aware Code: the code glows depending on the personal energy consumption (Gustafsson & Gyllenswärd, 2005)

2.2.4. Data journalism

To support text-based articles, printed newspapers and magazines have employed visual aids such as graphs, diagrams and sometimes even more complex infographics for centuries (Cairo, 2005, p. 15). Infographics have appeared regularly in the news since the late 1930s (Meyer, 1997, p. 18). Journalism offers a particularly important domain for benefiting infographics. Infographics in the context of journalism are aimed at helping readers to investigate cause and effect, to allow for quantitative comparisons, to present alternatives and contrary cases, and to assist in decision-making (Bogost, Ferarri, & Schweizer, 2010, p. 38).

Data journalism is a nascent term that emphasizes the informative and argumentative roles of data and visualization when coupled with journalism (http://datajournalism.stanford.edu). Beyond text-based articles, it deals with visualization as a new medium that can effectively deliver data-oriented contents. This new field is receiving much current attention from InfoVis scientists, graphic and interaction designers, statisticians, as well as professional journalists and writers. When the experts from diverse background collaborate, they create interactive and sophisticated visualizations more quickly with complex datasets well beyond a simple, static bar or pie

chart from ten by ten spreadsheets. *The New York Times* (http://www.nytimes.com) and the *Guardian* (http://www.guardian.co.uk) among other online news sites, regularly publish interactive visualizations concerning current issues, such as elections and natural disasters. The visualizations function as editorial content and make political, social, and cultural arguments (Figure 15), unlike older printed graphics that merely fortified written articles as supplementary material.

Segel and Heer (2010) analyzed the genres of narrative visualization, a term to explain the situation that online journalists exploit visualization techniques to deliver their narratives effectively: magazine style, annotated chart, partitioned poster, flow chart, comic strip, slide show, film/video/animation. In addition, they discussed the role of interactivity in generating different levels of balance between author-driven stories (linear messages as traditional films) and reader-driven ones (exploratory tasks without prescribed order of images).

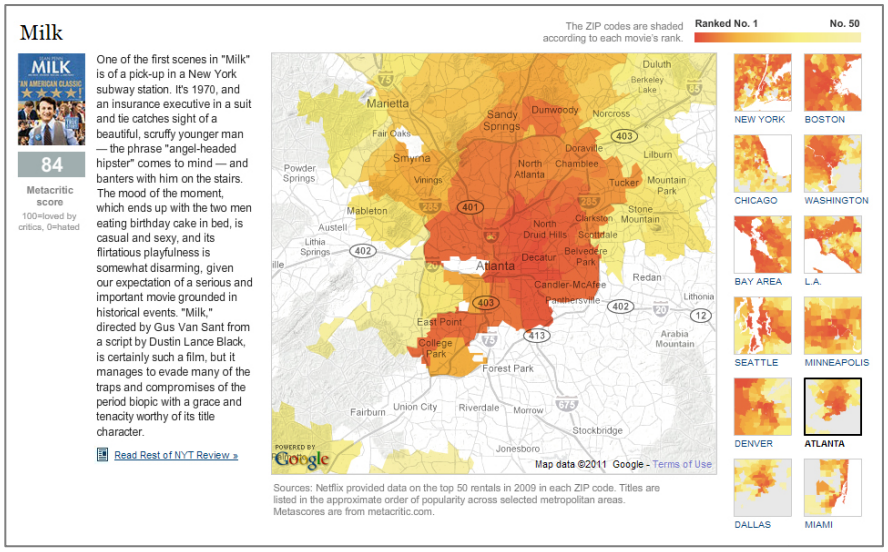

Figure 15. A Peek Into Netflix Queues: Heatmap-based visualization of Netflix rental patterns (http://www.nytimes.com/interactive/2010/01/10/nyregion/20100110-netflix-map.html)

So far, I reviewed several noticeable currents in information visualization, graphic design, HCI and journalism. To summarize, information visualization expands their

research agenda to cover the aesthetics and rhetoric of visualization, but computer scientists have not built robust theories for them; graphic designers have started to access to crude data and direct them to the widened realm of information design; HCI research for persuasion utilizes visualization as a way of idea implementation; journalism vendors acknowledge the power of data and publish data-intensified interactive graphics. From all of these relevant domains, I learn the others' approaches to my interest and find problematic spaces. In the following section, I describe how I develop the research questions from these learning and findings.

2.3. Research questions

This section introduces the research questions that my thesis will strive to answer. I derive them from an analysis of the current approaches—both what I learned and adopted for my research on visualization as digital media study—and more importantly, what I identify as deficiencies in current approaches. This grounds the problem space and further solidifies research questions that I will explore in the thesis.

2.3.1. Deficiency in research of related fields

Scholars and practitioners from different backgrounds such as computer science, graphic design, and communication studies have begun to plant flags in the unconquered world of visualization. Their involvement brings a renewed emphasis on the aesthetic values and applications of visualization to ensure its appeal to a wider audience. In addition, these relevant fields attempt to identify the diverse phenomena around visualization for social uses in their own ways.

Each field continues to shape the overall intellectual body through their methodologies for production, exhibition, and assessment. InfoVis scientists and graphic designers have expanded the possible forms of data representation by inventing new algorithms and creating unique visual styles. HCI scholars and journalists think the social use of visualizations through different types of media. Engineering-oriented researches attempt to formulate the cognitive and persuasive effects of visualization. My research benefit these existing theories and methods to some extent. However, I argue that there still remain neglected aspects in the big picture. This discussion provokes the research questions of my thesis.

First, in researching visualization as a sole subject of digital media studies, there is lack of discourses on *the nature of visualization as digital media.* In particular, I focus on the new opportunities of aesthetics and rhetoric of data visualization enabled by digital technology, because there two are the foundations in approaching to the essence of new media although they are often considered too broad or exhaustive. Yet the aesthetics and rhetoric focusing on visualization are intermittently mentioned in the related research field but in a shallow manner. I see the absence of adequate discussions on this subject as a research opportunity.

As I discuss the rhetoric and aesthetics of visualization, this thesis is meant to reveal the hidden aspects of visualization that was not very proximate to the interests of previous research. By investigating the neglected aspects of visualization research, I argue how the visualization of my discussion is distinguished from early definitions of visualization: how can visualization be a cultural interface that brings social and political concerns? In contrast to other visualization research, my thesis investigates *visualization*

as a product of digitalized processes that has a potential to have cultural and social impacts. With the theories constructed through the investigation of the primary problem (i.e. the influence of computation on visualization), the following step is about *designing* visualization that focuses on the uniquely discussed aspects of visualization in this thesis.

Based on the primary problem and the design-focused direction, my research questions are:

- Q1: What are the influences of computation on visualization? To be specific, how does computation affect the aesthetics and the rhetoric of visualization?
- Q2: How does visualization function as a cultural interface that enables new forms of social expression?
- Q3: In answering Q1 and Q2, how can "design research" as a research method inform the theories and practices of computational visualization?

The two following subsections discuss the first two research questions that are the uncovered aspects of visualization and deficiencies in the existing research.

2.3.2. Q1: New affordances of computational visualization

Although the term visualization does not explicitly address the use of a computer, it is presumably considered as the result of computer-based work, not only in the previously discussed disciplines but also among laypeople who sporadically encounter visualizations within everyday media. Moreover, among InfoVis research in computer science, the use of computing technology as a precondition of visualization is clear. For example, one popular definition of InfoVis from computer science is "the use of computer-supported, interactive visual representations of data to amplify cognition"

(Card et al., 1999, p. 6). Ironically, due to the obvious perception that visualization is produced by the power of computer, there has not been ample questioning and discussion about the role of digital technology in visualization creation. Pointing to such missing discussions, I raise a question: What kinds of new opportunities has computation brought to visualization-empowered media?

One immediate and easy answer is that making visualization with a computer is faster than with hands. The typical process of producing visualizations starts with generating and trimming data. The content is then aesthetically represented in mostly two-dimensional space with visual primitives. Computers can do these complex jobs more effectively than unaided humans. Yet, production is not the only occasion where computing technology excels. According to Manovich (2001, p. 19), borrowing computing technology in the phase of production does not automatically elevate a medium as new medium. Instead, the use of digital technology for distribution and exhibition is what distinguishes new media from old ones (although this definition does not tell us about the effects of computer-based distribution on the aesthetics of what is being distributed). Visualizations in general are created to be accessible to both intended audience groups as well as the public at large. Most cases of computational visualization are viewed and experienced by users through screen-based media such as website or software. According to this definition of digital medium, for the visualization research as a subject of digital media studies, I maintain a holistic sphere of visualization from production to exhibition and to sharing.

Beyond the use of computational algorithms and computer graphic software in generating the data-based images, the focus of my thesis as a digital media scholarly

work is the characteristics of these visual media that are not be achieved with traditional and analogue methods. In other words, the core of my thesis is the discussion on the influence of computation on visualization-based media. To cover the in-and-out of visualization, this theoretical approach has two folds. On one hand, what are the new visual forms and *aesthetics* emerging in computational production, exhibition, and distribution? On the other hand, due to the influx of computation what kinds of *rhetorical* advantages has visualization gained? Here is the reason why I choose aesthetics and rhetoric as the foci of the thesis.

Aesthetics of digital media have been discussed thoroughly with different perspectives. For example, Bolter and Grusin (2000) analyze the heritage of old media in the form of new media with the concept of remediation. Murray (1997) explained aesthetics of digital media as the pleasure of use, the novel experiences of immersion, agency and transformation. However, aesthetics of visualization as a specific genre of medium has sufficiently investigated neither by digital media scholars nor by other theoreticians in different fields.

In a similar manner, rhetoric is an established field of study with its own history. Recently "rhetoric in digital media" and "rhetoric in design" are somewhat popular themes among theorists. The emerging rhetoric in and around digital media has been discussed by many scholars (e.g., Losh's Virtualpolitik (2009), Electronic literacy (Gurak, 2001), Bogost's procedural rhetoric (2007)). Since Buchanan (1985), rhetoric has been one of the most central gears in the construction of theory in design studies, often as a narrower domain visual rhetoric (e.g., Forlizzi & Lebbon, 2002; Gallagher & Martin, & Ma, 2012). However, advanced discussions on visualization as an emerging genre of

design are rare. In sum, in spite of both robust scholarly traditions and growing interests in digital media, *aesthetics and rhetoric that contributes to visualization specifically* have been only intermittently mentioned in the related research fields in a shallow manner.

2.3.3. Q2: Designing visualization as a cultural interface

The second question is about the new roles of visualization when it stresses the aesthetics and rhetoric. Based on the theories formed by answering the first question, I introduce a new concept of visualization. To represent this new role for social expression, I adopt a term "cultural interface," which was originally suggested by Manovich (2001). In addition to defining the unique roles of visualizations by theoretical analysis and synthesis, I build a visualization system and demonstrate the new concept of the visualization that I suggest previously.

This approach is similar to what InfoVis researchers take when they first suggest a focus of visualization research can aim. For example, Donath et al. (2006) introduced "social visualization" with their project of visualizing computer-mediated conversations. I plan to design a visualization system that exemplify the design criteria form the theory part and generalize the design elements in which the criteria are applied.

2.4. Design research as methodology

In seeking to answer to the two research questions, my thesis contains work as both a theorist and a practitioner. To encompass this duality, as well as to seek out the most appropriate approach to the research topic, I identify my research methodology as *design research*. I present diverse approaches in design research that can be applied to digital media studies in general and computational visualization in particular.

Design research is multifaceted; it covers the two faces of my thesis—theory and practice. By theory, I present the discourse of design knowledge that provides both the design research community and the digital media community with the language to understand and analyze the aesthetics and rhetoric of visualization. To search for the language, I investigate the tradition of aesthetics and rhetoric of data visualization from the 20th century's modernist design. In addition to design history, I investigate theories from aesthetics, rhetoric, and media studies. By practice, I first suggest design criteria of visualization based on the previously built theories. I apply the criteria to my own visualization, so that I can demonstrate the theories. As a digital media practitioner, I build visualization systems with the state-of-the art technologies. Additionally, I discuss how well the criteria are implemented and enhance them, which ultimately contribute to building knowledge in both design research and digital media communities.

First I introduce what design research is at large and what specific knowledge can be produced through design research. Second, I present how visualization is positioned as a central gear in design research. In the following two subsections, I discuss why and how the two sides of design research—theory and practice respectively—become methodologies for the study of visualization and digital media at large.

2.4.1. Design knowledge as outcome of design research

In the 1970s, a design educator and scholar, Archer (1979) claimed that the problems that designers face were ill-defined. He argued that the solutions were allowed to have small amount of misfit between the requirements and the provisions, unlike science's concern with formulation and testing of theory. Moreover, in contrast to humanities that justify scholars in the critical and philosophical study of it without

contributing to its content, design demands designers to communicate their attention between problems and solutions through modeling such as drawings, diagrams, and physical representations. His notion was in line with the needs of design educators and industrial designers at that time who wanted to set up a distinctive discipline of design on its own beyond a job of surface decoration.

Expanding the view of design as problem-solving practices or a practical discipline built on its own methods of modeling, designers seek to develop domain-independent approaches to theory and research in design (Cross, 2001). *Design research* is not a field for technical research aiming to immediately inform the development, but an inquiry focused on producing a *contribution of knowledge* so it is recognized as a liberal art of technological culture (Buchanan, 1992; Cross, 1999; Zimmerman, Forlizzi, & Everson, 2007). Design research aims at the development, articulation and communication of design knowledge, whose forms are peculiar to the awareness and ability of a designer (Cross, 1999).

Then what is this design knowledge that is the outcome of design research? Many scholars have put forth definitions to classify design knowledge. Below I introduce two models.

Cross (1999) suggests that the sources of the design knowledge are people, processes and products. The first subject of design research is the human ability to design. Second, the study of processes revolves around the techniques that aid the designer and the modeling methods. Finally, design knowledge resides in the forms, materials, and finishes of the products that embody design attributes. In sum, what designer research should do is developing a more formal knowledge of shape and configuration, the

theoretical studies of design morphology. The knowledge from people, processes, and products formulate three categories of design research: design epistemology (study of designerly ways of knowing), design praxiology (study of the practices and processes of design), and design phenomenology (study of the form and configuration of artifacts).

In addition to Cross's model, Fallman (2008) added another aspect that design should consider—the context, which is an important factor in interaction design. His model of design research in interaction design has a shape of a triangle: design practice, design exploration, and design studies (Figure 16). Design practice tends to toward commercial interaction design organization where designers engage in building successful products and services mostly in a multidisciplinary team. Driven by ideals and theories, design exploration spans outside of current paradigms so that it adapts interpretative attitudes of many humanities disciplines and acknowledges the issues of aesthetics. Design studies resemble traditional academic disciplines where a body of knowledge is accumulated through theorizing philosophical notions.

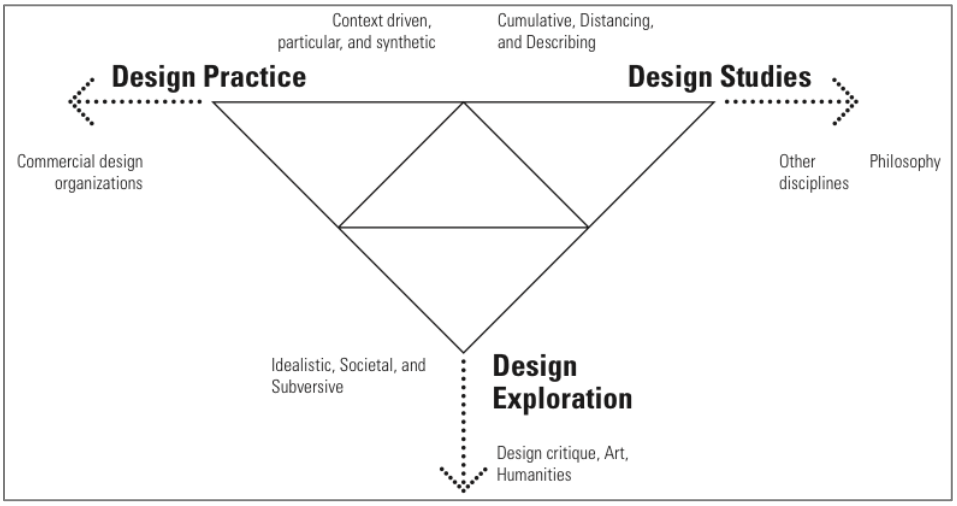

Figure 16. A model of interaction design research (Fallman, 2008)

2.4.2. Situating visualization in design research

Scholars who advocate design research as a distinctive discipline characterize design as integrative discipline (Buchanan, 1992), and approach its diverse genres from a theoretical perspective rather than practical domains.

Buchanan (1992) indicates the four areas of design—sign (symbolic and visual communication), things (material objects), action (activities and organized services) and thoughts (environments for living, working, playing and learning). He suggests that these areas are interconnected, grounding the unique character of design research that distinguishes it from science and art. I argue that visualization crosses many of these design genres. Following his taxonomy, visualization is an artifact for visual communication (sign), as well as an important part of products (material objects). The use of visualization creates experiences of action, and provokes thoughts in diverse environments.

Fallman (2003) also conceptualizes what design "really is." His three accounts of design are conservative, romantic, and pragmatic. The conservative account refers to the traditional sense of design: problem solving of ill-defined and unstructured problem through a rational process. The romantic account gives prominence to the role of designers as creative individuals having artistic freedom. According to the pragmatic account, design is engaged directly in a specific design problem that is culturally situated, requires heterogeneous tools and materials as well as tacit knowledge. He stresses that design-oriented research can be conducted only when none of these three accounts are abandoned. Analyzing visualization through his perspective, it is used for problem-solving purposes as either a method among design processes or a final outcome

(conservative account). Visualization is designed with much aesthetic attention like an artwork and investigating the aesthetics of visual media is a meaningful activity (romantic account). Finally, for the discussion on the social effects of visualization, it is important to understand the diverse contexts in which visualization are created, distributed and interpreted (pragmatic account).

A recent research paper in a journal, *Information Visualization* discusses the role of design in information visualization (Vande Moere & Purchase, 2011). Vande Moere and Purchase argue that design research has thrived for several years crossing many fields adjourning InfoVis such as human-computer interaction, but there are only a few academic publications that specifically focus on issues relating to InfoVis. Addressing the increasing involvement of designers in InfoVis, they exemplify that graphic designers enhance the appearance of visualization techniques based on new algorithms. Conversely, new representational methods can be invented inspired by the works of graphic designers. To them, design refers to aesthetics as the attractiveness of a static visual form, in the context of triangular design requirements, soundness, attractiveness, and utility. They finally suggest a framework of “design in visualization research (Figure 17)”adapting Fallman’s model.

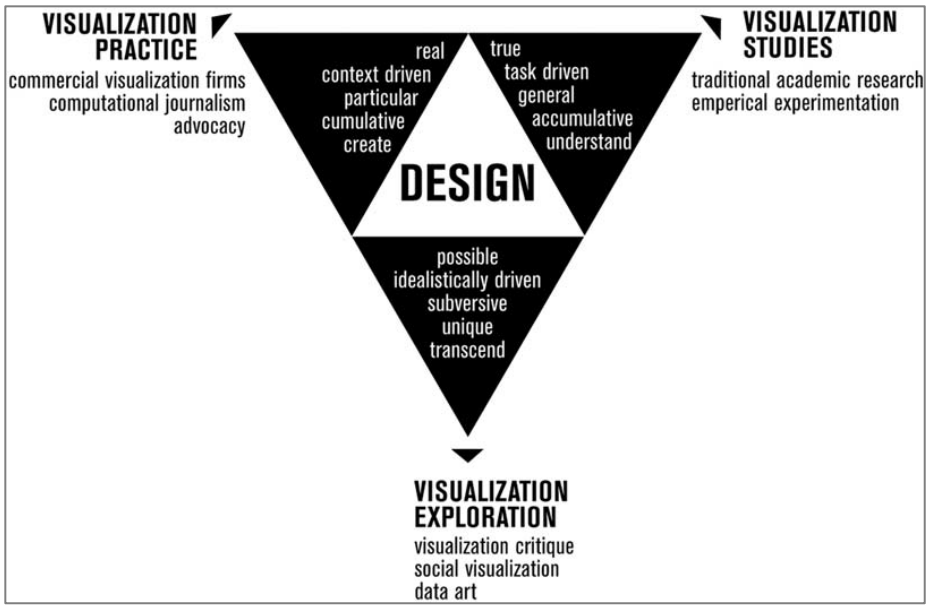

Figure 17. A model of three roles of design in information visualization research

The two parts of my thesis—theory and practice—are positioned on this model. The theory part that I analyze the aesthetics and rhetoric of visualization is towards to the side "visualization studies." For this, I cover literature from both traditional disciplines such as aesthetics, rhetoric and graphic design, and interdisciplinary fields such as digital humanities, digital rhetoric, and interaction design. By practice, I demonstrate the theories I developed; as Drucker (2009) clarified, putting theory into practice by building things has forced our ideas to become concrete. My design projects neither commercially driven nor a pure artwork, rather they would be positioned in between "visualization practices" and "visualization exploration" (Drucker, 2009, p.31)

2.4.3. Modern graphic design for digital media discourses

Building theoretical knowledge that is not concerned about the "making" nature of design activity is an important part of design research, as discussed under the phrase of "design studies" by Fallman (2008). Here I discuss how this specific path of design

research can contribute to the discourses on computational visualization in digital media studies.

On one hand, scholars have labored to define and characterize new media by linking them to older media with established analytic languages such as narratives (Murray, 1997) and film (Manovich, 2001). On the other hand, discussions on new media may focus on a specific genre such as videogames (Bogost, 2007). Accumulation of such work has built the theoretical foundation for digital media studies. To construct my thesis, I adapt these methodologies; *I focus on a specific genre of digital media that is computational visualization and the central lens to analyze visualization is graphic design.*

I argue that there are strong connections between modern graphic design and contemporary computational visualization in many aspects. First, when facing modern graphic design, especially from the Swiss/International style, our visceral response tells us that it resemblances the geometric and minimal appearance of contemporary visualization. The ground of the shared visual aesthetics between modern graphic design and contemporary visualization is the desire to pursue objectivity, rationality, and clarity. Second, both Swiss/International style of graphic design and data visualization are actively employed in journalism, marketing, and education. As a specific purpose of communication, they have been used for political purposes; the poster has been an important propaganda tool in the 20th century, and recently, visualization, as already seen in the Obama chart (Figure 2). Therefore, it is a valid approach to discuss the aesthetics and rhetoric of visualization by relating visualization to modern graphic design.

Visualization is a huge and emerging area in the contemporary graphic design scene just like Graphical User Interface (GUI) design, for example, became a hot topic in the 1990's. However, there is not sufficient development of discourses on visualization among the design community; although many books about visualization have been published in current years, they are mostly collection of exemplary work by several visualization pioneers. Still, the "textbooks" in visualization design are Tufte's books (1990, 1997, 2001) originally published in the 1980s and 1990s, which do not contain a detailed understanding of the effect of digital technology on their contents. Consequently, for both design practitioners and scholars, there has been a significant lack of the accumulated and shared knowledge on the principles of visualization design in the digital era.

For these reasons, I argue that now is an opportune time to discuss computational visualization as an important genre of design studies from diverse perspectives. I explore the historical ties between computational visualization and modern graphic design comparing their visual styles and social roles. I also examine visualization as a type of interaction design for novel user experience. In doing so, the theory part of my research will contribute to the body of knowledge in design studies in addition to the digital media studies. I envision this work as the last chapter in a future edition of graphic design history book.

2.4.4. Digital media studies through critical design practices

When I use "design practices" to describe a research methodology in this thesis, I do not refer to the activity of making commercial products or services. Instead, it means the design activity to create digital media artifacts that can be positioned between the two

extremes of a commercial artifact or a piece of artwork. The design projects that I initiate and discuss in the thesis contribute to the body of design knowledge driven by problem defining-solving activities with critical attitudes.

Visualization design starts with finding problems of the given data, or finding the appropriate data for a given problem. For either case, a critical approach to discovering problematic contexts is essential. Design has discovered such problems and strived to solve them through making things (Zimmerman et al., 2007). The problems are not always so technical that sciences or engineering can solve them in their established ways (i.e. hypothetical testing), but ones that design techniques with critical attitudes can explore.

Since the late 1990s, there have been alternative design practice paths as a response to the submissive role of design as corporation-driven production or a supportive tool in HCI research. Blurring the boundary of artists' approach to production and critique, designers have explored the capability and the role of design in criticizing the materialized world, increasing societal awareness, provoking unconscious issues, and motivating and enabling political actions. Despite the short history, alternative design practices come through a wide variety of design activities, including *participatory design* workshops with community members. Participatory design reveals the unseen problems and stirs the discussion on them not only through the final outcomes including product, graphic, interaction design, and conceptual proposals but also the people-involved design process. Another representative approach in this line of design is called *critical design*. It does not aim for a specific solution to a problem, but rather an open-ended discussion that is less predetermined and more unanticipated (Dunne & Raby, 2005).

Admittedly, design projects that can be labeled as “critical” or “speculative” are often indirect, sarcastic, and even ambivalent. Furthermore, critical design envisions the future in imaginative ways, although these projects start with the current scientifically proven status. What my thesis takes from the approaches of critical design research is not their temporal context—imaginary design speculating what might happen in the future—but the role of designing objects (in my case it will be visualization-embedded media) to present knowledge and social problems and trigger people’s responses to them. In sum, the primary goal of my design practices is not making a commercial artifact of polished visualization, although representation techniques are borrowed from the conventional forms of InfoVis and graphic design. Moreover, my practices do not lie in visionary art making practices, but are aligned as alternative design research that can appeal to interaction designers and HCI researchers.

When it comes to design (whichever genre it is sourced in, whether interaction, information, and even critical and speculative) and art, the historical methods of assessment are less explicit and less persuasive, especially for engineers and scientists. Of course artists do not have to objectively show the audiences the effects of their artwork as engineers do with their systems. However, when the created artifacts are defined as a work of design rather than art, the creators should maintain the attitude of designers as a storyteller through logical reasoning—how they choose the contents, how they construct the form, how their original intention is portrayed to the audiences through the artifacts, and how the messages grow in the inner minds of the audiences and ultimately influence their attitudes and behavior. Hence, to pursue a solid design research process and goal, the practices in this thesis include a critique part of the practice.

Critiquing an artifact as a part of design research is different from evaluating a system in traditional HCI and InfoVis. If a visualization technique is aesthetically pleasing and unique, but not functional enough to channel information in an intuitive and accurate manner, InfoVis scientists usually conclude that the system is not successful. When they evaluate the social aspects of visualization (e.g., how people discuss visualizations on *ManyEyes*), InfoVis researchers adopt traditional HCI-oriented methods, making use of quantitative analysis of users' activities or qualitative methods such as interviews or surveys (Viégas, Wattenberg, van Ham, Kriss, & McKeon, 2007; Viégas, Wattenberg, & Feinberg, 2009). In contrast to the engineering approach for system evaluation, design researchers and theory-oriented scholars have suggested new ways of "assessment," aligning with the expanding HCI research boundaries. By adopting this term from art criticism, they tend to avoid the term "evaluation" to stress an alternative approach from the current qualitative and quantitative methods. One of the most marginal emerging HCI topics—categorized under "miscellaneous" according to the ACM keyword system—may be sustainable HCI. Some examples of the new assessment methods for this space include discourses from art critiques (DiSalvo, Boehner, Knouf, & Sengers, 2009), critical theories from media studies and aesthetics (J. Bardzell, 2009), and even feminism (S. Bardzell, 2010). The critique of the design practice in this thesis will adopt such critical approaches.

Chapter 3

The rhetoric of data visualization

The first research question of this thesis is “What are the influences of computation on visualization? To be specific, how does computation affect the rhetoric and the aesthetics of visualization?” This chapter is the rhetoric part of the two large domains of investigation. As I clarified earlier, although rhetoric has been a core research interest for design thinkers and digital media scholars, *rhetoric on visualization* and specifically *the influence of computation on rhetoric of visualization* has not been thoroughly discussed. Here I analyze this problem in the following organization. In the first section, I introduce several essential theories of rhetoric as particularly applied to the domain of visualization; the theories of communication, visual rhetoric, and rhetoric in design. Next, I focus on the rhetoric of non-digital visual media. I start with the social involvement of modern graphic design as a form of printed media and present classical visualization examples from that era. The last two sections are for the discussion on the influence of digital technology on the rhetoric of visualization. I then investigate how the classical boundaries of rhetoric and visual rhetoric have become expanded with the influx of computation, with the specific examples of computational visualizations.

3.1. Theories for the rhetoric of visualization

Rhetoric is one of the oldest independent disciplines of human inquiry and it serves an important theoretical background in the other fields such as communication, design, and visual culture studies. For example, Craig (1999) outlines seven traditions of

communication theory—rhetoric, semiotic, phenomenological, cybernetic, sociopsychological, sociocultural, and critical. Even in a communication model from information sciences, the theories of rhetoric explain the effects of the messages in the process of encoding and decoding. In this section, I introduce communication theories, visual rhetoric, and rhetoric in design, all of which are necessary in order to understand the rhetoric of data visualization.

3.1.1. Communication theories

Media studies come alongside the study of theory of communication (Clarke, 2010, p. 131). Under the meaning, "the imparting, conveying, exchange of ideas, knowledge and information," the term communication can be applied in two different ways—social connectivity and material contact. Social connectivity, or the communality of communication means the multiple and conditional understanding of messages based on social grounds prior to individual intentions. Material contact, or the materiality of communication, concerns the physical and technological infrastructure that conveys messages. Thus, communication is both a social phenomenon and media technical phenomenon (Clarke, 2010, pp. 132-133).

Clarke (2010) introduces the two perspectives of social and technological relation of communication. According to him, communication theories construct and deconstruct the distinction between social and technological aspects. Shannon and Weaver (1949) distinguished communication (sociological context) from media (the channel) (Figure 18). In Shannon's diagram, the central channel is composed of three parts; transmitter that encodes messages into signals, and a receiver that *decodes* messages and finally sends the message to the final destination. Between the transmitter and the receiver, there invades

media-specific noise source. The noise represents opportunities for rhetoric that can create diverse ways of interpretation beyond the pure information. The media-specificity explains that each representational technology such as film or audio has its own distinctive way of sending and receiving messages.

Clarke points out that the constructive model of communication best restates the nature of information—"the materiality of communication media always determines a potential discrepancy between the message as sent and the message as received." I also argue that Shannon's diagram helps to understand the process of computational visualization. In this case, visualization matches the communication media that codes and decodes the messages. The "noise" that is added through visualization becomes a part of messages at the end in addition to the pure data source. In this chapter, I focus on how computational visualization as media technology creates its own meaningful "noises" in the communication phase.

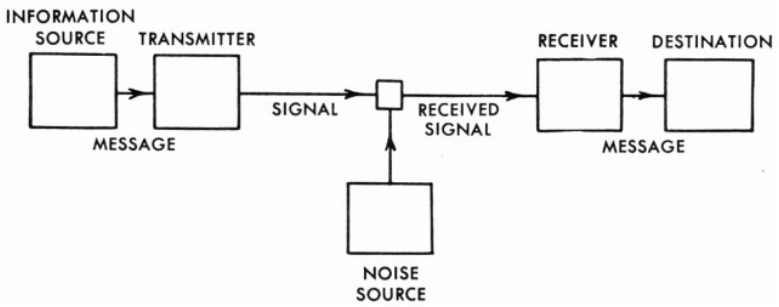

Figure 18. Schematic diagram of a general communication system suggested by Shannon (Clarke, 2010, p. 134).

3.1.2. Visual rhetoric

Rhetoric is the art of persuasion. The classical concept of rhetoric, dating back to ancient Greece, refers to public speaking. Rhetoric has been discussed according to the three categories. Ethos is the credibility or the ethical appeal conveyed by the character of

the respectable speaker or writer; pathos is an appeal to the audience's emotions; logos means the use of logical reasoning and its effective evidence (Aristotle, 2008). The 2,500-year old rhetoric was understood as an art for oratory, direct persuasion, and political purposes.

Beyond the oral forms, rhetoric was extended to account for new modes of inscription such as writing, painting, sculpture and other media. These expanded modes of rhetoric do not necessarily make direct appeals to persuasion as its oratory cousin, but refer to active expression that help authors accomplish their goals. Also the goal of the author shifts from the desired and particular end to a desirable possibility space for interpretation (Bogost, 2007, pp. 19-20).

Some fields such as visual culture studies and media studies have expanded the understanding of rhetoric to include visual representation. The field of visual rhetoric explores many ways in which visual elements are used to influence people's attitudes, opinions, and beliefs through the analysis of photographs, drawings, graphs, tables, and motion pictures (Hill & Helmers, 2004). Although visual communication, unlike oral rhetoric, does not function as a means of direct persuasion, images can be more vivid than text or speech and therefore can be more easily manipulated, evoking visceral responses. In order to fill in the lack of the direct persuasion, visual rhetoric requires visual arguments that supply viewers with reasons for accepting a point of view (Bogost, 2007).

Rhetoric is also affected by the timing of a given message. Besides the three aspects of classical rhetoric—Ethos, Pathos, and Logos—, another critical concept in rhetoric is Kairos. Kairos is originally translated as "the season of speaking" in the

ancient Greek. Recent theorists expand this narrow definition of Kairos to include the contextual influence of a speaker's argument. The message may be shaped by the specific cultural and political contexts of the time and its location in a particular region or country. Thus, Kairos refers to the relative interpretation by the audiences due to their physical, perceptual, and historical context, which varies from one to another. As Kostelnick (2008) suggests, *visual literacy* or *social rhetoric* is another lens through which we can understand the audiences. Visual literacy consists of the interpretive skills of images, which are highly specialized cultural conventions.

3.1.3. Theories of Rhetoric in design

Now I focus on design as a specific domain where rhetoric becomes a key lens to theorize. I introduce several theoretical approaches as the foundation for the social roles of design. Design thinker, Richard Buchanan is a prominent scholar who opened the discussion on rhetoric in the field of design. Branching from his theories, other scholars also discussed the rhetoric of design.

3.1.3.1 Buchanan on rhetoric

Buchanan (1985; 2001) has discussed rhetoric of, or and, design in several articles. His scope of design is neither visual communication nor even digital media. Rather he focuses on designed objects that are the matter of industrial design. However, it is worthwhile to review his classical notion of rhetoric in design, because he discusses the crucial aspects of design as "mediating agency of influence between designers and their intended audience" (Buchanan, 1985). He argues that the increasing distance between technologists and designers has increased the needs of rhetorical theories in design. In other words, because technology is not concerned about values and benefits for human

community, a suitable theory is necessary to make designed objects more intelligible, to provide the basis for public criticism and to evaluate the design.

Buchanan asserts that design works as “an avenue of persuasion” because, by presenting an audience with a new product, designers directly influence individuals and communities, change attitudes and values, and shape society in fundamental ways. He treats this influence of technology and design as a subject of persuasion. Relating to the traditional techniques of rhetoric, he suggests two ways of design practice—one is an approach to design with familiarity and materials that meet specific needs; the other is to identify practical applications based on the understanding that technology is not purely scientific reasoning or principle but an art of deliberation about the issues of practical action. He expands this idea of design practice to conclude “design is a debate among opposing views about such matters as technology, practical life, the place of emotion and expression in the living environment, and a host of other concerns that make up the texture of postmodern, postindustrial living.”

According to Buchanan (1985), the designer is creating a persuasive argument that comes to life whenever a user considers or uses a product as a means to some end. He specifies the three elements of design arguments—*technological reasoning*, *character*, and *emotion*. These three match the three concepts of rhetoric; logos, ethos, and pathos respectively. First, technological reasoning is based on the scientific principles that construct objects for use. It is also based on human circumstances that allow variety of settings of users’ own choice. There is a risk that poor technological reasoning may be concealed. Second, character or ethos refers to the way designers represent themselves in products. Designers imbue their personal qualities to give confidence to users. Kitsch and

irony are the devices in this category. Third, emotion or pathos gives design the status of a fine art. It comes from physical contact with objects. Feeling is conveyed in the experience of movement made either in gestures made in using an object or in the shift of visual attention. This approach helps an audience to entertain new possibilities for practical living.

3.1.3.2 Other research on rhetoric and visual communication design

With the foundation of Buchanan's work, several design researchers and theorists discuss rhetoric in a narrower domain of design with specific interests.

Forlizzi and Lebbon are one of those (2002). They introduce the rhetorical view of communication design—designers create arguments to persuade an audience by referencing key values and connecting social values, beyond simply formal expression and even iconic or symbolic messages that need viewers' decoding to some degree. The rhetorical view allows both designers and viewers to *co-construct meaning through the visual message*. Ultimately, it creates the possibility for social agreement within a pluralistic society. For maximum effects, it is necessary to understand properly the audience who they are designing for. Forlizzi and Lebbon present two case studies, both of which are public campaign posters initiated by governmental bodies. Although the design process, which employs user-centered design methods such as focus groups and evaluation, is different from the one for the 20th century propaganda posters, the goal of the design remains—to raise awareness of specific social problems.

A more recent article published in *Design Issues* introduces a new concept, Visual Wellbeing, intersecting the two intellectual traditions—rhetoric and design (Gallagher et al., 2011). Gallagher et al. argue that ancient rhetoric resembles modern design, because

both, as art and a practice, deal with “functional, contextual, and social aspects of language and symbol systems. They find two specific concepts in rhetoric—vividness (Enargeia) and wellbeing (Eudaimonia)—to analyze visual objects. The theory of Visual Wellbeing explores from universal assumptions about aesthetics to human wellbeing within the situated human experience and creativity. This critical framework creates opportunities for invention and generates analytic power to illuminate meanings and evaluate visual phenomenon.” They specify the boundary of its applicable domain within culturally situated and community related situations, including sustainable design, designing for democracy or civic participation, and questions of emotion and design.

The first section of the chapter on rhetoric presents the founding theories that can be harnessed when focusing on computation and data visualization. First, communication theories stress that communication is affected by both social and technological aspects. Second, while introducing visual rhetoric with the classical devices including Ethos, Pathos, Logos, and Kairos, I stressed that visual literacy or social rhetoric reflects the cultural conventions at the phase of interpretation. Last, the surveys on the rhetoric and design informs that design objects can be culturally situated and trigger the awareness of social problems. These theories provides the fundamentals that how visualization, as a communication method, visual medium, and a design object, can equipped with rhetorical functions. Based on this, the following chapters specifically discuss the rhetoric on visualization.

3.2. Rhetoric of non-digital visualization

Although data visualization exploits digital technology in the production phase, its rhetoric as a visual medium is still rooted in the tradition of non-digital media. In this

sense, it is a valuable approach to explore the social and cultural aspects of the modern graphic design in the non-digital era. Graphic design has contributed to communication as an effective delivery method of ideas and arguments, in line with the advances of media technology. For example, in the era of the mass production of printed media, posters were popular for the advertisement of commercial products or events and the promotion of governmental policy. With the understanding of the social involvement of graphic design in the modern era, I analyze the early examples of data visualization with a focus on the rhetorical devices. Finally, I present well-known artifices of visualizations that aim at deceiving people with tricks in the process of coding data.

3.2.1. Social involvement of printed media in the 20th century

Looking into the 20th century's graphic design scene, one can witness that designers acknowledged their social responsibility and realized it through their works, which is a reaction to the government's political use of graphic design during war times. During this time, universal visual language was envisioned and developed often for educational purposes.

3.2.1.1 Use for propaganda

Modernists in the early decades of the 20th century purposely revealed the capabilities of technical inventions. Avant-garde artists' understanding of media and materials led them to find a visual language to translate the social meaning of the radical technological changes (Drucker & McVarish, 2009, p.188). In this context, propaganda campaigns were being mounted by national governments to build support among civilian populations. Due to the omnipresence of visual images and the easy acceptance by illiterate people, governments used posters to appeal to laypeople, and even to enlighten

and raise awareness. Politicians created and manipulated print-based graphics such as posters in order to imbue people with their ideology in a similar way as radio and newspapers. Propaganda posters are characterized by its flat graphics and simplified images, which are used to elide the differences between familiar objects and the symbols of war. For example, a poster by Hans Rudi Erdt, reiterate a style used to advertise vacations and leisure activities. This familiarization of war activity allowed war to seem more like a continuity than a disruption of everyday patterns of life (Figure 19) (Drucker & McVarish, 2009, p.196).

Figure 19. Hans Rudi Erdt, U-boats Out! 1916
(http://www.spartacus.schoolnet.co.uk/ARTrudierdt.htm)

Information campaigns in post-revolutionary Russia had the task of educating a broad class of illiterate workers. (Drucker & McVarish, 2009, p. 199). In the 1920s and 1930s, designers in the Soviet Union developed a modern and photomontage-based style that they applied to posters and other propaganda visual media. This visual aesthetics was

not only informative but also promotes each person's productivity that contributes to the well-being of the collectives.

Designers used schematic graphics that eliminated concrete details in favor of diagrammatic elements and the form of an idealized flow chart. This new visual language expressed the government's long-term goals and economic plans. For example, Elena Semenova's poster from the 1920s is a notable example of an artist using visualization techniques as a part of the artifacts to reinforce the ideology of the new epoch in Russian history–collectivism, socialism and totalitarianism (Figure 20). I will further analyze the semiotic and rhetoric of this poster focusing on the visualization aspects in chapter 3.2.3.

Figure 20. Elena Semenova's poster in the 1920's

Against governmental propaganda, counter-production of posters appeared as well. Maud Lavin provides a perceptive and analytical historical context for early political graphics (Lavin, 2002). Several exemplary designers are Hannah Hoch, Ellen Auerbach, Grete Stern, and John Heartfield. They used photomontage—mixed-face typography, hodgepodge cuts and figures, and high-tension collage—as a potent propaganda weapon and the images met with immediate identification and comprehension by the working class. Collage and photomontage were techniques of

disruption—of the illusion of pictured space, of the cultural expectations of public discourse, and of the political effects of familiar directives (Figure 21).

Figure 21. John Heartfield, anti-Nazi propaganda poster, 1935
(http://www.intentional.co.uk/glass/thesis/thesis.htm)

3.2.1.2 Visual symbols for educational purposes

During the World War I, the governments involved in the war designed posters to make the public familiar with the military agendas. For example, a British poster contrasts the various shapes of planes and ships from Germany and Britain (Figure 22). The symmetrical proposition of the elements in the poster is one feature of contemporary infographics. Besides the formal similarity, this poster functions as an educational medium; ideally it helps non-military people identify the enemy craft as Drucker and McVarish (2009) notes—"the capacity to recognize the enemy relied on visual cues for which graphic rehearsals were the best education" (p.198).

Figure 22. Public Warning, British poster, 1919. (http://www.museumoflondon.org.uk)

Danziger (2008) praises his work saying “A particularly compelling example comes from Otto Neurath, the Austrian sociologist responsible for inventing the Isotype pictographic language in 1937.(…) Neurath was interested in using visual language as a means to communicate across (verbal) language barriers, as well as cultural, economic, and educational ones. He argued the need for ‘consistent visualization,’ suggesting that such a language could ‘humanize and democratize the world of knowledge of and of intellectual activity.’ (Neurath, 1937). Isotype itself became the precursor to the now universally familiar iconographic language used to identify locations of services (such as in airports), serve as warning signs, and, most recognizably, tell us where to look for restrooms.” (Figure 23)

Zambrano and Engelhardt (2008) addresses the correspondences between Nearath’s Isotype and the current trend of information visualization in which more data become accessible and beneficial for social empowerment. They consider that Neurath’s Isotype has influenced the international pictograms found at airports or railway stations, and in newspaper infographics in the 70’s as well. In addition to the formal heritage, they

argue that two fundamental ideas of Isotype—"clarity of thinking" and "serving the needs of society"—have become the base of the social use, in other words, "diagrams for the masses" of information visualization such as Gapminder.

Figure 23. Otto Neurath, Isotype, 1936
(http://www.cabinetmagazine.org/issues/24/pendle.php)

3.2.2. Rhetorical analysis of historical examples

Data visualization is created in order to first *encode* creators' intention and second allow for viewers' *decoding of the message*. Along with the process of encoding and decoding, I analyze comparable visualizations with the terms from semiotics and rhetoric. For the semiotic analysis, I adopt the terminologies by Barthes including linguistic messages (denotational and conotational), noncoded iconic messages, and coded iconic messages.

I focus on digital technology on the communication and persuasion of visualization in the later part of this chapter. Now I select two images from the 19th and 20th century that can be considered to be ancestors to contemporary visualization for social and political uses. In both images, data are encoded into visual elements with the intent to influence the public but with different rhetorical approaches. I describe what

these images are, what the socio-political contexts of the time are, how this context influences the viewers, and thus how the creator's intention is interpreted by the viewers.

An early persuasive use of visualization is epidemiologist John Snow's map of death from cholera (Figure 24) (Tufte, 1983). A street map shows central London in 1854 and includes the following data: how many people died from cholera, where they died, and where water pumps were located. Snow drew horizontal lines stacked along the streets to indicate the deaths at each address. The location of each water pump is displayed with a circle and a small text label. At that time, no evidence existed whether water or air caused cholera. Through this map, Snow intended to visualize the correlation between the water quality and the outbreak of cholera. In this visualization, viewers can discover a key abnormality in the outbreak—the number of death is much higher around the water pump on Broad Street.

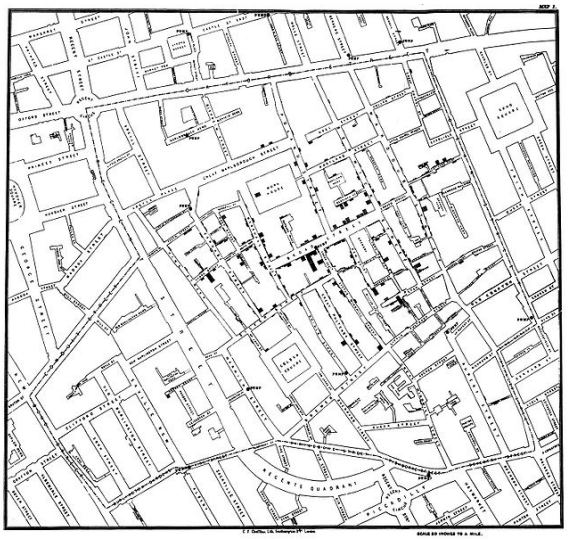

Figure 24. Original map made by John Snow in 1854. Cholera cases are highlighted in black.

The most salient part of the image contains both noncoded iconic images such as the stack of bars and linguistic message such as the name of street and the location of the suspicious water pump. Through these scientific and direct mappings, this visualization-

centered image influences the rational side of viewers (appealing to their Logos. I also argue that ethos plays an important role in persuading the viewers; Snow was a renowned physician, thus non-experts were more inclined to interpret the image without criticism or mistrust.

In the previously shown Soviet propaganda poster (Figure 20), the central noncoded elements are the photographic images of Stalin and the worker with the machine. The photomontage encodes the power relationship between the dictator and the target audiences. Viewers can decode a meaning from this relationship: Stalin compels each worker to work harder. This message of hard work is reinforced by the three circles, which depict and contrast the poor, adequate, and high productivity of the three social groups. The coded messages delivered through the overlapped circles are that the production system is interlinked between individuals and that their efforts are related to the whole (Drucker & McVarish, 2009).

At the same time, the bar charts and the illustrations of specific products in the circles, as well as the relationships between elements in the composition explain objective states, which partially affect the viewer's logos. More importantly, the high contrast of colors and the dense composition of the photomontage overpowers the diagrams, which appeals to the viewers' pathos. Lastly, this poster can be interpreted in greatly different ways depending on the viewers' temporal and social contexts (kiaros). In contemporary North American culture, some may consider this poster as a merely "cool" image with only a hazy connection to a totalitarian regime, not a reflection of how society should be structured.

3.2.3. Classical artifices for deceiving visualizations

Visualization requires the transforming of predominantly quantitative data, as it is considered to be relatively more objective than subjectively selected contents. Consequently, it is axiomatic that visualization is relatively less impeded by the intrusion of subjectivity of the creators than other visual media such as paintings or even photography. Thus, visualization itself as an image can be considered as a noncoded iconic message. Throughout the entire process of transforming data, however, from parsing favorable towards a certain party to using culturally biased colors, visualization is vulnerable to the creator's subjectivity and even their intention to deceive the viewers. Even though visualization carries textual annotations and can show purely objective images, the coded iconic message among the significations of images is the focus of this thesis on visualization.

Before I discuss the influence of digital media on the rhetoric of visualization, I present several classical artifices for visualizations that aim to deceive people with the tricks at the phase of processing and data and creating images. A handful literature has already indicated how to make a false knowledge through data manipulation and various charts, in other words, "how to lie with statistics" (Huff & Geis, 1973). Although most current visualizations obey modernists' rules such as clarity, objectivity, and simplicity, there still remain chances that designers can imbue cultural meaning unconsciously. These artifices are still often found in even more deliberate ways.

3.2.3.1 Selection of favorable data set

Irrefutably visualization designers must use some specific dataset or a part of it to support their arguments. However, since much of what the visualization will convey is

determined by the selection of data, it becomes obvious for a designer to use favorable data. Conversely, they exclude data that are not helpful or even harmful in stressing their opinions. How data are selected and trimmed can be a crucial factor since they determine the appearance of an image. Therefore, to yield a satisfying image that fortifies their arguments, creators should be careful during the phase of retrieving data.

One famous visualization that tries to lie at the level of data selection is the Obama chart (Figure 2). As previously addressed, this visualization contrasts the performance of the Obama Administration and the Bush administration, purposely putting more positive impression on the Obama's side. In addition, being labeled "U.S. Job Loss (Dec. 2007 to Jan. 2010)", this visualization leads viewers to perceive that the "number" of job losses has dramatically decreases.

However, it was indicated that the dataset for the graph was carefully selected to support the current administration ('Creekside chat', 2010; 'Political Math', 2010). The cited source of "job loss" data is the Bureau of Labor Statistics, which provides raw datasets related to the trend of employment/unemployment. In addition, the graph provides formatting options and the time frame of the raw data. Among the extensive options, the creator's choice was "1-month net change in employment." Although the number of monthly jobs lost decreased, the total number of unemployed is still rising. In other words, if we make another visualization from the original dataset, "the number of employees," in the similar visual aesthetics of the Obama graph, people have been losing jobs steadily since 2009 (Figure 25). Admittedly, the bars on our self-created graph do not start from zero, which is another noteworthy technique that can exaggerate the changes between the values of a variable. However, I tailored the difference of the

numbers in two nearby horizontal grids as a tenth of that in the original graph. Thus, the height of each bar in the original graph is equal to ten times the difference in height between two adjacent bars in our graph.

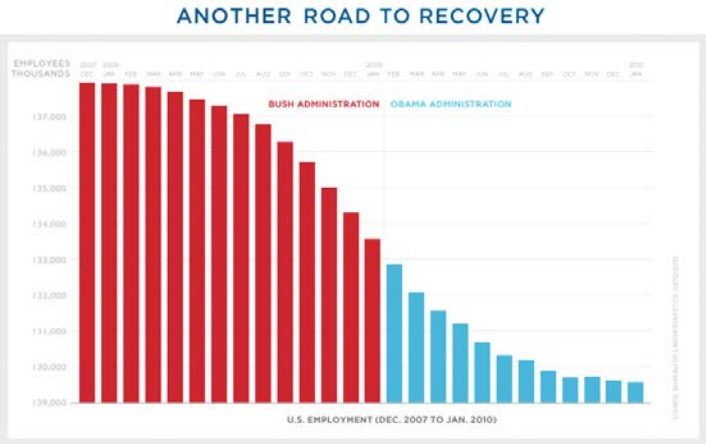

Figure 25. Number of Employees in the U.S. (Dec. 2007 - Jan. 2010), created as a modification of Figure 2. *Road to Recovery* (http://my.barackobama.com/page/content/recoveryanniversary).

3.2.3.2 Use of decorative graphics

Contemporary visualizations usually depict data in a familiar modernistic visual style: a minimal use of decoration ("data Ink" according to Tufte), perceptual principles such as gestalt, geometric layout, orderly typography, and simple color compositions. This aesthetics attempts a universal form and aims to objectify cultural diversity. Thus visualizations with such aesthetics appear economical and perceptually transparent (Kostelnick, 2004). In this sense, some might argue that modernistic clarity can increase the credibility of the visualization, or ethos as well as the effective delivery of knowledge (logos).

However, recent research provides some evidence that added ornaments, which have been criticized by Tufte (1983) as *chartjunk*, can actually help viewers remember the delivered messages (Bateman et al., 2010). Moreover, we see many visualizations that

include more decorative illustrations and photographs, especially for narrative purposes (Segel & Heer, 2009).

I believe that such supporting imagery can influence pathos by tying the data into connotative meaning while also improving aesthetic impact. I can also apply the notion of chartjunk in reverse; ornamental graphical elements can hinder pure delivery of dispassionate data, which implies that designers could use them to conceal a weakness in the data. If this happens, viewers should negotiate more carefully with the visualization not to be deceived, and decode the meaning of the added graphical elements separately from the data display.

3.2.3.3 Other miscellaneous tricks

Another technique that is found in the Obama chart is the subtle manipulation of colors, which may hinder neutral perception. Miscellaneous tricks of modifying contrast and brightness of colors may result in manipulative sensation connecting to cultural codes. In the Obama graph, the red color of the Bush Administration is much darker than the original Republican color. By contrast, the Obama color was brightened to sky blue that culturally has the aura of integrity.

Bubble charts are also commonly manipulated to exert a similar illusion. While visualizing given numbers, designers should change the area of the bubbles that represent the numbers, not the diameter, proportionally. A visualization of the job gain and loss in the U.S. is an obvious example (Figure 26). Similar distortions are repeated in many other visualizations. For example, in a visualization about how the European Union is funded and spends its money by country, the visual use of triangles can be misleading (Figure 27). Similar to the bubble chart, the triangles are scaled by height, not by area.

Pyramid-like visualizations often use the same technique by mistake or to intentionally distort (Figure 28). The value of each division in the pseudo 3D shapes was reflected only in the height, not in the area of the faced planes or the volume. Thus, the contrast between the numbers appears much stronger than its actual gap.

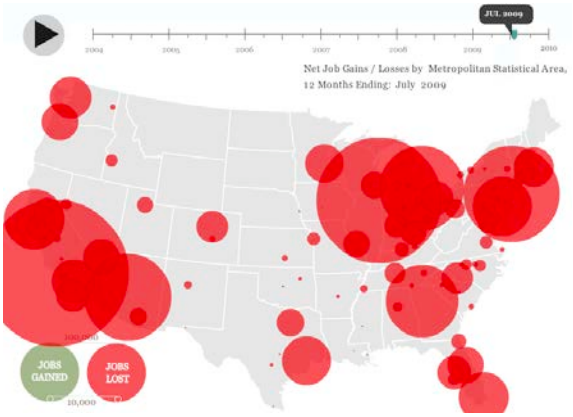

Figure 26. Job gain and loss in the U.S. (http://tipstrategies.com/archive/geography-of-jobs)

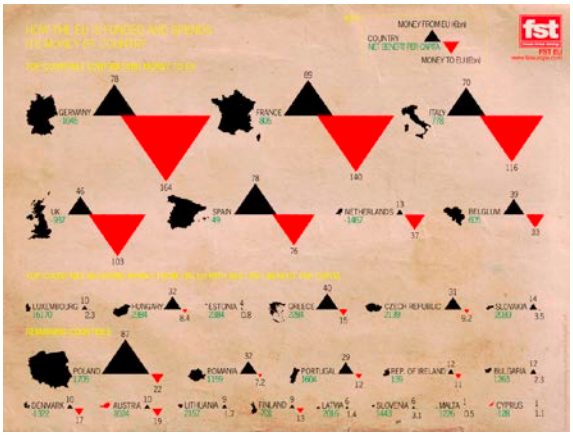

Figure 27. European union fund (http://www.fsteurope.com/news/eu-income-tax-revealed)

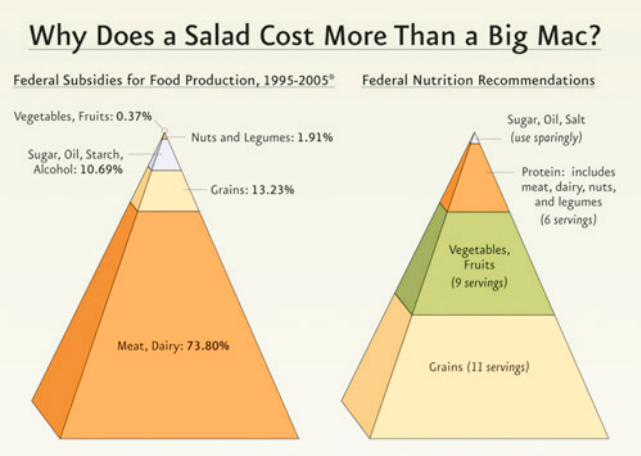

Figure 28. Federal subsides for food and nutrition recommendation (http://www.pcrm.org/magazine/gm07autumn/health pork.html)

In this section, I introduced a larger context, historical examples, and well-known tricks of visualization that are not produced with digital technology. The purpose of this chapter is not articulating that the rhetorical devices and strategies of visualization are different depending on the intervention of digital technology. In fact, the rhetoric of non-digital visualization remains in the digitally produced visualizations. In the next chapter, I move forward to the rhetoric of digital environment that will be theoretical background to discuss the influence of computation on the rhetoric of visualization at the end.

3.3. Expansion of rhetoric in digital environment

In the previous sections, I discussed the rhetoric of visualization with the rhetorical theories that do not focus on digital technology. Also I introduced some examples of non-digital visual media and visualizations. Here I investigate the related theories to rhetoric that are explicitly influenced by the digital environment. Those theories have been discussed under terms such as digital rhetoric, procedural rhetoric and cyberliteracy/digital media literacy. I introduce these theories and how some can be used and why others are not appropriate for the discussion of visualization.

3.3.1. Views on digital rhetoric

Carnegie (2009) argues that awareness of interfaces brings rhetorical opportunities. She presents three modes of interactivity that are multi-directionality, manipulability, and presence and describes how they work to engage audiences. Under the *multi-directional interaction*, messages are related to the previous messages, and the feedback between senders and receivers matters. Writing and sharing online reviews is one example of multi-directional activity. *Manipulability* of digital media allows users to influence the form and the content of communication. Wikipedia, for example, has a high level of manipulability since it allows the general public to create, modify, and discuss. *Presence,* as a more psychological phenomenon, refers to a user's sense of being present in a "place."

Liz Losh (2009) presents an extensive and holistic definition of *digital rhetoric* in her book *Virtualpolitiks*, in which she discusses the emerging political actions on the Internet. Losh's definitions on digital rhetoric are useful to understand the diverse levels of rhetorical phenomena driven by digital technology. Her four different definitions of digital rhetoric are:

1. The conventions of new digital genres that are used for everyday discourse, as well as for special occasions, in average people's lives.
2. Public rhetoric, often in the form of political messages from government institutions, which is represented or recorded through digital technology and disseminated via electronic distributed networks.
3. The emerging scholarly discipline concerned with the rhetorical interpretation of computer-generated media as objects of study.

4. Mathematical theories of communication from the field of information science, many of which attempt to quantify the amount of uncertainty in a given linguistic exchange or the likely paths through which messages travel. (Losh, 2009, pp. 48-49)

The first definition, "the rhetorical conventions of new digital genres in everyday discourse" implies that unlike the readers of traditional printed books, digital readers now leave many traces in their online viewing habits because editing of individual texts has been meliorated. In this definition, the users of public digital media such as the website of city hall may not be actively engaged in persuasion or argument. Expanding the classical rhetoric *kairos*, which originally describes a specific season for speaking, in everyday activities as "rhetorical," the language of given messages may be shaped by specific contexts and time-contingent opportunities for public events such as voting (Losh, 2009, pp. 49-50, p. 52).

She also asserts that understanding the conventions of many new digital genres that have socially regulated forms and are composed as files of electronic code. Some genres are more associated with the presence of particular moral values; for example, why the general public thinks that making a first-person shooter video game is intrinsically more morally suspect than creating a word-processing document? (Losh, 2009, pp. 54-56). She explains the rhetorical practices in digital genres by relating to several pedagogical models including the dialogic model, the storytelling model, and the situated-learning model. In the *dialogic model*, people practice social rituals of gift exchange such as email conversations and file upload/download in their computer-mediated communication. The *storytelling model* grants participants the authority to build

narratives as a cultural production while using story-generating media. The *situated-learning model* explains how the experience of non-traditional literacy in a novel medium such as video games can be transferred to the real world context because the virtual environments offer secure learning spaces. Carnegie's concept of "presence" is in line with the situated-learning model, since both address how digital interactive artifacts enable spatial transport.

The second definition, "public rhetoric via electronic distributed networks or hypertext" clearly explains the phenomena that we are witnessing the profusion of computational media used to deliver and to enforce political messages. Since the public rhetoric is more immediate and visible, the policy makers form an alliance with marketers to target the four fields in government rhetoric—institutional branding, public diplomacy, social marketing, and risk communication. Institutional branding is realized through visual iconography and used to amplify official messages. Ideally being less hegemonic and more committed to grassroots, public diplomacy focuses on two-way dialogues by understanding how the message is interpreted by diverse societies and developing tools for conversation and persuasion. Public rhetoric through social marketing fosters open discussion, deliberation, debate, consensus, and compromise rather than deploying implicit, undebated, and even unconscious appeals.

The next definition, "the rhetorical analysis of new media in scholarly communities," focuses on digital rhetoric as a new and individual field of study. Losh points out two shortcomings in the critical work done in digital rhetoric to date. First, she claims that the research objects in current new media scholarship are not very relevant to the interest of the public at large. Second, she argues that the theories to study digital

rhetoric are exclusively from literary criticism and other traditional humanities disciplines; for a more intimate understanding of the systemic constraints that govern the representation, processing, and retrieval of information, relevant literature from technologists is necessary.

Lastly, as a recap of the current ignorance in humanities-driven digital rhetoric studies, Losh suggests the fourth definition, “the rhetoric of information theory as a distinct field associated with computer science”. She empathizes that “information is created at the place where technology and rhetoric intersect.” Then she introduces the communication theory by Claude Shannon and Warren Weaver, which I included at the beginning of this chapter (Figure 18).

3.3.2. Procedural rhetoric

Researchers in digital media scholarship focus on the unique traits of digital media to discuss digital rhetoric. One lens to explore digital rhetoric is *procedularity*, which refers to the inherent procedural nature of digital media in executing a series of rules. Coining *procedural rhetoric*, Bogost (2007) argues that the procedurality of digital media places a greater emphasis on the expressive capacity by showing the rules of execution. That is, designers have new rhetorical tools that can open conversations and make claims about “how things work.” According to Bosogt, “because procedurality is intrinsic and fundamental to computers, and because computers are much more flexible as an inscription medium than human agents, they are particularly suited to procedural expression” (Bogost, 2007, p.10). Whereas visual rhetoric makes arguments via images, procedural rhetoric does through engagement with the processes and the interactive capacities of digital media. Video game, in Bogost's view, is an ideal medium that

enables players to participate in the expression of rhetoric. For example, in *The McDonald's Videogame*, an anti-advertisement game whose goal is to censure or disparage a company rather than to support it, players are encouraged to make "immoral" choices procedurally in multiple situations.

Procedural rhetoric is widely accepted among scholars who study the educational and persuasive effects of video games because it is the first and probably the only concrete theory to discuss the novel rhetoric driven by digital media. In this situation, researchers in other digital media studies domains including InfoVis reference procedural rhetoric as a background theory when discussing the rhetoric of data visualization. However, I argue that procedural rhetoric is not appropriate to explain the rhetoric of all kinds of visualization.

Researchers in the field of InfoVis cite the theory of procedural rhetoric when discussing the rhetoric of interactive visualizations. For example, Hullman and Diakopoulos (2011) use procedural rhetoric in discussing interactivity as one of the editorial layers of narrative visualizations (four editorial layers include the data, visual representation, textual annotations, and interactivity.) They suggest *anchoring* and *filtering* as two techniques of procedural rhetoric. Anchoring means that the point of interpretation and the priority of perceived information are anchored to the visual configuration, from the default view with spatial ordering of elements to animated scenes. Filtering, a more explicit interactive technique refers that users can explore the data and even personalize through menu choices and search bar.

Adopting the term procedural rhetoric for the rhetorical features driven by interactive features is seemingly reasonable, since procedural rhetoric successfully

explains the new types of rhetorical situations occurring within digital environment. In addition, the "narrative information visualization," even sounds to be a sibling term of "interactive narrative." However, as the name of procedural rhetoric implies, I argue that this theory is only appropriate when there is an explicit procedure of narratives, not the simple non-linear switching of hyperlinked scenes, in the interactive medium. The procedure is the main factor to create narratives that is not simply change of scenes by clicking a button, but a development of stories through the greater changes of characters or surroundings.

Procedurality is not merely the process of programming codes in video games, but also one of the key characteristics of video games as interactive narratives. Most of the introduced video games by Bogost are fully charged with specific temporal and spatial settings, explicit goal of games, and procedural gameplay. When procedurality is applied to visualization, it should not simply mean the animation of visualization techniques or the swap of bars or graphs according to data filtering.

There are many genres of games from a simple puzzle-like game such as Bejeweled that requires repetitive actions to a real-world simulation game such as Sims that players enjoy for a much longer time with complex and multi-level strategies. Computational visualization is not yet as diverse as video games in terms of the complexity of interactivity; most of visualizations exhibited on the Internet have very limited cues of interaction. Thus, saying "procedural rhetoric is the theoretical background to understand the rhetoric of interactive visualization (Hullman & Diakopoulos, 2011)" is not fully convincing. It even reminds me of a (classical) debate between narratologist and ludologists; ludologists, who treat video game as an

independent and new medium that does not inherit the narrative devices from literature, argue that it is not reasonable to find explicit narrative in some games such as Tetris. I argue procedural rhetoric makes sense only when visualizations have explicit procedure and persuasive narratives that are seen in political or anti-advertisement video games.

3.3.3. Digital media literacy and political engagement

Expanded from the classical meaning of rhetoric focusing the oral practice and visual rhetoric, rhetoric is digital environment refers to the study of how symbols including language, sound, and images communicate as persuading and motivating forces. Those symbols appear in different temporal and spatial forms in the emerging technologies of digital communication (Gurak, 2001, p. 6). Thus, how these new forms of symbols are delivered and interpreted is an underlying issue in studying rhetoric in digital era; this issue has been discussed under the field of *digital media literacy or cyberliteracy*. Gurak (2001) asserts that for the discussion on cyberliteracy, we need to understand not only how to use the technology but also how to live with it, participate in it, and take control of it. He characterizes cyberliteracy, saying it is neither purely a print literacy nor an oral literacy; the novel form of communication does not only remediate old printed media but also adapts the oral tradition of social networks. Thus cyberliteracy changes how people read, speak, think, and interact with others in many ways (Gurak, 2001, p. 14).

In a research project funded by Knight foundation, Joseph Kahne and their colleagues investigate the relationship between digital media literacy education and online political engagement in a longitude period. They define media literacy as “the ability to access, analyze, evaluate, and create messages in a variety of forms” extending

the traditional understanding of literacy to the new media environment (Kahne, Freezell, & Lee, 2012).

They argue that digital media technologies are a central component of civic and political life especially for young people, and digital media literacy can be a way to promote online forms of civic and political engagement. The online civic and political activities include seeking out information, producing contents, and engaging in dialogues on political topics. One important role of media literacy is that it allows the youth to be exposed to divergent viewpoints, which promotes a better understanding, reflection, and appreciation of these different viewpoints on complex issues. Kahne's other research also discusses the effects of such online experiences on offline participation such as voting for elections (Kahne & Sporte, 2008).

3.3.4. Participatory culture

The technological advances that blurred the boundary between producers and consumers can be discussed as a phenomenon in "participatory culture." In participatory culture, people have lower barriers to artistic expression and civic engagement, so they are encouraged to create new artifacts by mixing and matching existing content (Jenkins, 2006). Regarding data visualization, the number and the range of both producers and consumers of visualizations have expanded. As discussed earlier, ordinary people who used to be the consumer of everyday visualizations have become the source of data. In addition, visualization authoring tools such as *ManyEyes* enables people to produce their own visualizations easily, then discuss and exhibit them through other social media channels.

One socio-technological trend that has enforced the needs of the visualization authoring tools for the general public is the greater accessibility of data. Global-scale organizations such as United Nations and OECD and the national census or statistics bureaus open the data from their own research to the public. A vast quantity of the democratized data, which is downloadable on the web, is about demographics such as population change, economic growth and health related issues, and environment/climate change. These data seem more relevant to human life in general than scientific data that are more focused in their application. Thus, the data have the potential to become stories and even arguments when handed to creative people and exposed afterward to the general public.

Web 2.0 technologies have opened a stage where data from governmental and global institutions can be reborn. Besides *ManyEyes*, there exist many other visualization authoring tools that are popular among everyday users. Wordle, Tableau Public, Swivel, Spicynodes are among those tools. The purposes of these sites are diverse, from simple fun to educational aids. Among them, rhetorical usages can easily be witnessed. The tags attached to the visualizations created on *ManyEyes* cover many political and social subjects (e.g., census, people, speech, education, health, obama, budget). According to a Wordle user survey, 50% of respondents agreed that they used Wordle to illustrate a point they were making (Viégas et al., 2009).

The rhetorical impact of visualizations spreads out more quickly in participatory culture in which creators and viewers from isolated locations can discuss and further engage in the driven issues. On *ManyEyes*, users can discuss specific visualizations and datasets as textual comment entries. Besides on-site communication, off-site discussion

grows in the context of the open web. Many collaborative visualization systems allow one to copy URLs or snapshots of created visualizations. The duplicated images are exposed to many more people, who can contemplate and discuss the delivered facts or arguments. In addition, if the images are reproduced on journalism websites in a timely manner, they can function as editorial content and arouse general readers' responses.

This section was about what rhetoricians theorized on the digital environment, including extensive definitions of digital rhetoric and procedural rhetoric. I also explained the phenomena in the digital era that bring new types of rhetoric such as cyber literacy and participatory culture. I adopt these vocabularies to analyze the rhetoric of computational data visualization later.

3.4. Influence of computation on the rhetoric of visualization

The last section of the chapter on rhetoric is a detailed discussion on the influence of computation. While I discuss the new affordances, I follow a typical design process of layer or data visualization—data/contents, contents, representational forms, and interactivity and platform. Prior to this discussion, I present the current discussions on the rhetoric of visualization by design and InfoVis researchers and indicate their weaknesses and limitations.

3.4.1. Current view on rhetoric in visualization research

Design critic Peter Hall empathizes that transparency, visual consistency, and users' effective control are crucial factors in designing visualizations for journalistic purposes (Hall, 2011). However, these objective aspects of visualization are not the only dominating elements in non-scientific purposes of visualizations. As recent research

published in the community of visualization has shown (e.g., narrative visualization (Segel & Heer, 2010) and visualization rhetoric (Hullman & Diakopoulos, 2011), other perspectives such as decorative figures and visual literacy has arisen as important aspects in this field. In these perspectives, rhetorical theories are applied in discussing the narrative aspects of visualizations.

The first research paper (Segel & Heer, 2010) on the storytelling of visualization published in the field of InfoVis does not explicitly employ rhetoric theories. However, it acknowledges the spectrum of *author-driven* and *reader-driven* storytelling in the various types of narrative visualizations. Segel and Heer argue that the genre of visualization, which is identified based on the composition of visual and textual elements and the level of interaction, mainly decides to which side the storytelling style is driven. On one hand, stronger author-driven storytelling visualizations heavily rely on messaging with no interactivity and are commonly seen in business presentation or educational videos whose goal is effective communication. On the other hand, a pure reader-driven visualization does not include the prescribed ordering of visual elements or a high degree of interactivity. Visualization software such as Tableau is an example, which supports tasks of data diagnostics, pattern discovery, and hypothesis formation.

This analysis opens a discussion on the spectrum of possible rhetoric of data visualization, since most interactive visualizations are positioned somewhere in the middle. In addition, it explains how the elements in the visualization are organized (i.e., the architecture of information design) and how much users have control over the contents are the important aspects of rhetoric.

However, this research has several limitations, which suggest spaces for further investigation. While discussing visual forms for communication, the boundaries that narrative visualization can encompass are not clear. It is somewhat understandable since the visualizations for the casual, everyday, and journalistic purposes loosely come across from simple charts to complex computational visualizations. Despite the blurred boundaries, several genres presented in this paper such as flow chart and comic strip are questionably categorized as "visualization," because they are conventional visual forms commonly seen in the sphere of information design (visual restructuring of processed data). Moreover, in "magazine style," the visualization does not seem to be the core part but additional to the body text. Based on these loose and expanded spaces of narrative visualization, it would not to be an overstatement to say that any diagrams on printed newspapers can be called narrative visualizations. More importantly, while categorizing the visual forms of narrative visualization, Sigel and Heer (2010) did not explicitly discuss the newly available forms driven by digital technology. Besides the notion of interactivity, the balance between author and reader is too general to be specifically applied to visualization and its journalistic use.

In other research, which takes a further step from the initial research on narrative visualization, Hullman and Diakopoulos (2011) suggest "Visualization Rhetoric" to frame effects in narrative visualization—as a way of understanding a users' interpretation process. I suppose they strategically did not define rhetoric in the traditional sense in their research paper; instead, they choose the term "bias," a common term used by visualization researchers. They characterize rhetoric as follows—"we use the term rhetoric to refer to the set of processes by which intended meanings are represented in the

visualization via a designer's choices and then shaped by individual end-user characteristics, contextual factors involving societal or cultural codes, and the end-user's interaction." This definition reflects the spectrum of author-driven and user-driven approaches of narrative visualization. In addition to this, it relates to the process of coding and encoding in communication theories and semiotics.

Their analysis framework of rhetorical techniques has four layers—data, representation, textual annotation, and interactivity. This approach is reasonable, because it reflects the typical process of visualization design and the distinction of narrative visualization (i.e., the volume of accompanied text is relatively larger). However, they fail to address interactivity or any other features of "interactive" visualization. The discussion on the unique rhetoric driven by the interaction is not adequate, which would interest InfoVis, digital media, and interaction design researchers. As stressed in this thesis and by other researchers as well, *interactivity is the key characteristic that defines InfoVis,* distinguishing it from static data chart. Thus, there arise further research opportunities: much deeper discussion on the new or improved rhetorical strategies brought by computation.

3.4.2. Users' creating and gathering data

When generated by the collective power of the public, data can be a unique rhetorical material, because such a wide range of social participation is unthinkable without digital technology. Each individual has become an original and meaningful source of data, not merely a small part of demographic data. Using mobile sensing technology that captures micro activities of a single person, people can participate in generating data (Paulos et al., 2008). For example, an individual's daily exercise data are

a useful source to track her physical condition. An even more powerful event occurs when the myriad of personally measured data are collected, shared and published to the general public for good will. In addition to the physically obtained data, collective online data such as messages on social networking services have become a source of a multitude of different interpretations on the news of the day.

In this environment, the *manipulability* of digital rhetoric plays a role; a myriad of people can leave their opinions about political and social issues (e.g., linguistic messages on Twitter). Such participation of the public results in massive amounts of raw text-based data. In online communities readers have been leaving comments on articles as an old form of participation, but now those textual comments can be a rhetorical resource through API (Application Programming Interface) technology (e.g., Community API of NYTimes.com).

Through *multi-directionality*, online journalism sites provide their readers with constrained but open spaces. Instead of merely reading or commenting on interesting content, the readers are invited to speculate on issues as they contribute to generating and evolving interactive contents. For example, NYTimes.com enabled readers to leave their thoughts on Osama bin Laden's death. Readers were able to plot their response on the graph against two axes (significant-to-insignificant and negative-to-positive), then they were able to leave a comment explaining their choice. Each light blue dot represents one comment and darker shades represent multiple comments made on a single point (Figure 29).

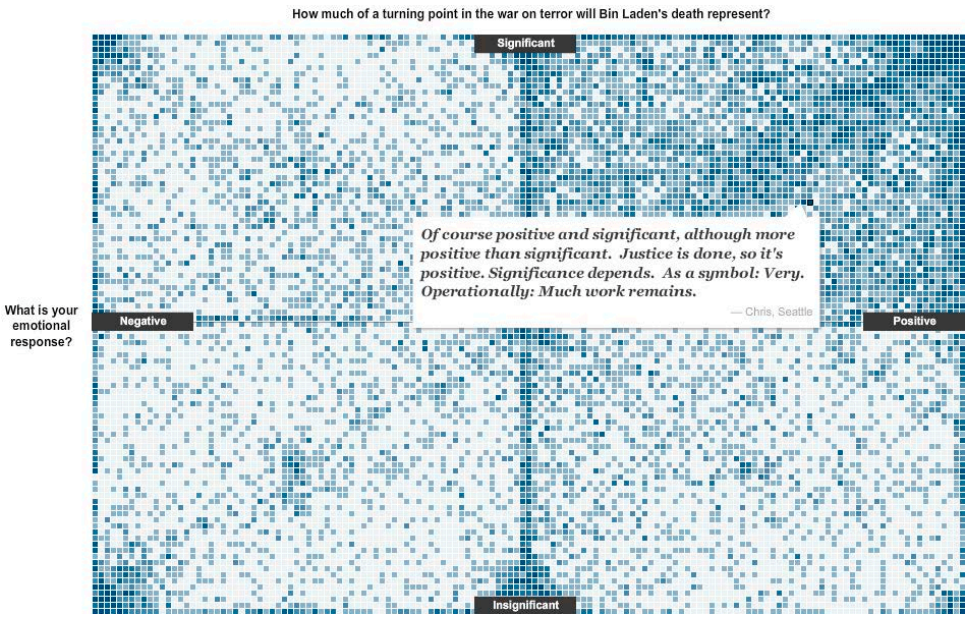

Figure 29. Visualization of the readers' responses on Osama bin Laden's death (http://www.nytimes.com/interactive/2011/05/03/us/20110503-osama-response.html)

Despite of the expanded access to a myriad of data sources, some data are still concealed by institutional bodies. In this context, people often volunteer in seeking hidden or missing data and building their own open databases as bottom-up approaches. There exist many online projects where ordinary Internet users provide the data sources and visualizations are exhibited based on the data through the participatory gathering.

For example, a website called Surveillance of Foot-and-Mouth Disease Info was an on-going project of data collection and mapping by the citizens in South Korea. In late 2010, foot-and-mouth disease broke out and it has been widely spread throughout a substantial size of the land. It became a serious concern not only to the health and food department of the Korean government but also to animal welfare and environmental activists, because the only reaction of the government was to bury livestock. Despite the public's increasing concerns, the government had not fully disclosed the data. Thus the citizens were not able to know the number and location of the animals. In response, a professor created a website where the citizens can enter data that contain the number of

burials, the locations, and the data source. Based on these gathered data, the application places markers on Google Maps. The project was not completed but remained in a primitive stage for a while, especially for the visualization part; the visualization is not automatically updated when new data entered. However, the most salient feature of this project is that it has started as the citizen's reaction to the governmental opacity. In other words, it exemplifies the use of visualization as a bottom-up and anti-government media.

In a similar manner, Atlanta Crime Maps allows the locals to report crime in their neighborhood. Then the reports are visualized on a Google map of Greater Atlanta area juxtaposed with timeline-based visualization showing the number of crimes and menu for filtering crime categories and geographical divisions (Figure 30).

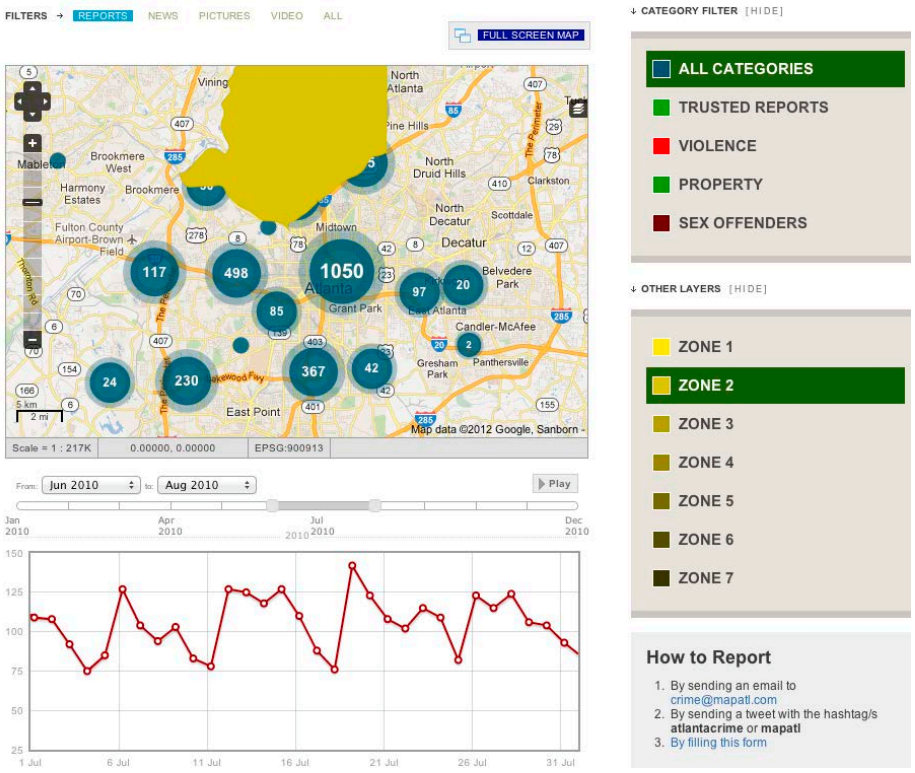

Figure 30. Atlanta Crime Maps (http://crime.mapatl.com/)

3.4.3. Experimental forms by digital production

In contrast to the immediate representation of data for which designers attempt to keep abstraction to a minimum, “artistic data visualization” can be enigmatic enough to keep a viewer interested while not being easy to solve (Viégas & Wattenberg, 2007). Through this strategy, abstract or artistic visualization can work well for expressing the designer's point of view and influencing viewer's pathos.

A good example of data-based and rhetorical artwork is a series of large-size photography work Jordan (Figure 4) that I presented earlier. The production methods heavily depend on digital technology; first he takes a picture of identical objects, then copies and manipulated using photo editing software (C. Jordan, personal communication, April 4, 2011). In conclusion, the abstract and artistic form stimulates the ethos and pathos of the viewers. The artist states that it raises questions about the roles and responsibilities of individuals in a collective that is increasingly enormous, incomprehensible, and overwhelming (Jordan, n.d.).

One of my previous research projects investigates the effects of ambient displays for behavior change (Kim et al., 2010). We developed a Mac OS X Dashboard widget that was displayed when a user actively called it. Based on the psychological theories for behavior change—people are ready to change themselves to adopt more ecofriendly habits such as conserving electricity when they are aware of the possible problems of their lifestyle—an ambient display, which users experience occasionally without its interfering with their primary tasks, is well suited to provide the feedback of their personal activities in a more subtle manner than direct information presentation.

We performed a comparative study with two different styles of visualization—abstract images (iconic representation) versus direct (indexical) representation. Both widgets render the user's computer usage statistics that consist of total uptime (the amount of time during which the computer is turned on) and idle time (the computer is turned on, but no input for more than 5 minutes). As a metaphor of iconic representation, we wanted objects or creatures that are scientifically related to the real environmental changes but typically hidden from our everyday lives. For this, we adopted underwater coral reefs and fish and expressed the data through the bleaching of coral reefs and the decreasing number of fish (Figure 31). For an indexical representation we used bar graphs, which emphasize the accuracy of individual values in the length of the bars that starts with the base of zero. It directly shows daily idle time (hh/mm) and total uptime (hh/mm) in bar graphs.

All the users of iconic visualization grasped that the coral reefs were damaged due to the increase of the idle time. In case of this negative change, 82.3% answered they tried to reduce idle time intentionally to save the coral reefs. The iconic representation helped make a connection between the presented information and the effects on the real world. Many users expressed emotional reactions using subjective words such as guilty, frustrated, sad, stressed out, felt pressure, while showing their will to recover the coral reefs. In case of recovery, they used subjective and positive expressions such as happy, encouraging, felt good, glad to see, and relief.

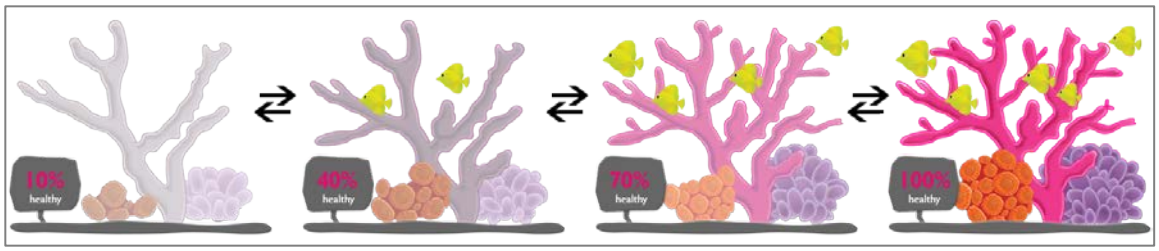

Figure 31. The reversible change of coral reefs and fish reflecting the computer usage time

3.4.4. Rhetoric of interactivity

InfoVis researchers have treated the interactivity of visualization as a pragmatic element, formalizing "interaction techniques" at the surface of visualization. The role of interaction is understood at the level of image change to support analytic tasks. The roles of interaction in InfoVis were once discussed with the following functions: *select*, *explore*, *reconfigure*, *encode*, *abstract/elaborate*, *filter*, and *connect* (Yi, Kang, Stasko, & Jacko, 2007). These general categories reflect the user's intent while interacting with visual systems, thus I argue that the task-oriented interactive techniques can enhance rhetorical properties of visualization systems as being related to the nature of interactivity that humanists discuss. However these primitive actions do not cover the higher level interaction that can occur in the larger context of visualization-embedded media. I discuss the rhetoric of interactivity in visualization according to the two levels: user-driven manipulation of visualization images and visualization-based media with procedurality.

3.4.4.1 Interaction for further exploration

When a single-page static visualization does not effectively deliver multi-dimensional messages, interactive features such as filtering, highlighting and zooming can be useful. The *manipulability* of interactive visualizations can prompt users to explore aggregative information from the perspective of their personal situation. Thus,

users can draw a variety of conclusions by manipulating data and views according to their personal goals or ideas (Bogos et al., 2010).

For example, a visualization of unemployment rates from January 2007 to September 2009, whose default line graph shows 8.6% total unemployment rate, allows users to filter race, sex, age, and education level (Figure 32). Through this interaction, one may investigate his or her own group in terms of the race, age, and educational level or compare various groups, so she can realize the significant gap between the demographic classifications that may trigger social and political problems. In sum, interactive visualization enables users to generate their own arguments and to obtain personal lessons while the high-level intention of the designers remains at the same time.

Figure 32. The Jobless Rate for People Like You: interactive visualization with filtering and highlighting functions (http://www.nytimes.com/interactive/2009/11/06/business/economy/unemployment-lines.html)

3.4.4.2 Procedural rhetoric through dialogues

As discussed in chapter 3.3one important theory of rhetoric in digital media studies is procedural rhetoric, which Bogost (2007) extensively discussed for potential of video games as political media.

Although the majority of exhibited computational visualizations deal with a limited number of data sets and simple interactive features, there exist several

visualization systems that exert the qualities of interactive narrative in a more complex way. Beyond the low-level interaction happening on the surface of visualization, interactivity allows users to explore and engage more deeply with the visualization system. Unlike single-image visualizations with limited interaction such as filtering and highlighting, this visualization project can be discussed well with the four characteristics of digital environment by Murray (2007)—participatory, spatial, procedural, and encyclopedic. It is needless to say that these projects share more qualities as interactive narrative medium with the political games that has procedural rhetoric.

As discussed earlier, *VoteEasy* is an visualization project and a web-based application that helps U.S. citizens find the political stance of the house and senate candidates in their district (Figure 33). The purpose of this project is to persuade a person to pay attention to what these candidates say about social and political issues. Thus the system helps the person choose the candidates whose opinions he or she can agree with. The system asks a person the questions about the issues, processes the answers, and matches them to the candidate's position.

In order to acquire data of the people's opinions and to compare them with those of candidates', the visualization system guides users from the first screen of selecting the state to the final one of seeing the details of the matched candidates. This is done in a linear narrative and procedural way. The first question that a user faces is "Where will you be voting this year?" Selecting a state leads her to the next page. The website asks more questions about other social issues and the system computes the rate of match to the candidates based on the answers. The results of the comparison are seen in conventional and aesthetically pleasing visualization techniques such as maps and bar graphs.

Besides the elegant design, I argue that what makes this project more satisfying and persuasive is its structure that effectively uses the procedural and participatory aspects of a digital medium. The procedural structure composed of easy-to-understand questions is a friendly and strategic form of dialogic model of digital rhetoric.

Figure 33. Question-and-answer based procedural structure of VoteEasy (http:// http://votesmart.org/voteeasy/)

3.4.5. Sharing beyond experiences within visualization

As discussed earlier, in the context of participatory culture, visualization artifacts do not stay at one specific channel, but are dispersed throughout multiple media resulting in further discussion. In addition, visualizations can become content for mash-up media.

3.4.5.1 Off-visualization Engagement

The rhetorical impact of visualizations spreads out more quickly today in the participatory and sharing environment. For example, *ManyEyes* supports users from all corners of the world and allows them to discuss specific visualizations and datasets as textual comment entries (Viégas et al., 2007). In addition to on-site communication, off-site discussion grows in the splintered online spaces through APIs. Many online visualization tools allow one to copy URLs or create snapshots of the created visualizations. The duplicated images are exposed to many more people, who can speculate on and discuss the delivered facts or arguments.

Visualization can even trigger real-world engagement. When *Nauge Vert* (green cloud, Figure 9) was presented in Helsinki in 2008, it invited the public to participate in a

more active way. Working with local activists and journalists, the artists advertised their exhibition and asked the citizen to join in an “unplug event.” The artists claim that the project creates “a visible form that relates institutions and their consumers and leads to the creation of a new type of citizenship and the transformation of a city” (Evans, n.d.).

3.4.5.2 Coherent identity throughout multiple platforms

In digital environment, traditional media can be mixed with other media and presented and shared through different channels. Visualization can be one of these complements, which supports persuasion. The web presentation of The State of the Union 2011 (Figure 34) is a good example of coupling digital rhetoric with the traditional public oratory. The numerous visualizations used in the presentation share the same visual styles (especially the Gotham font) with the administration's other visual artifacts. Therefore, while people are viewing this website, the branded visual environment with the accompanying video of the speech creates the sense of presence.

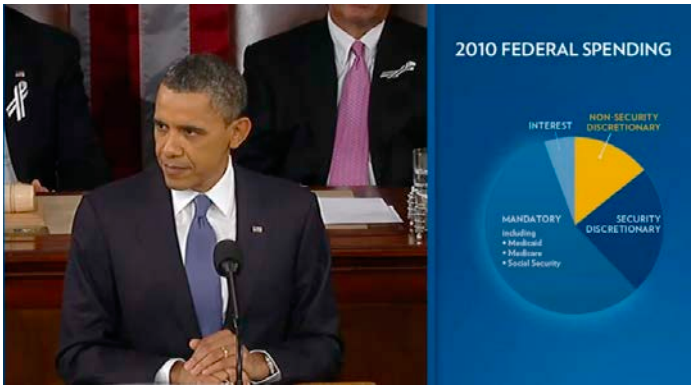

Figure 34. A snapshot of the State of the Union 2011 video available on http://www.whitehouse.gov/state-of-the-union-2011

This chapter has discussed the rhetoric of data visualization with a focus on the new affordances by computation. As I have presented the problem spaces and the consequent research questions of this thesis, the rhetoric of visualization as a research

subject has not been adequately discussed, especially with a perspective to see visualization as a digital production, social medium, and designed object. To resolve this problem, I first approached this topic by reviewing and identifying relevant studies on rhetoric from visual rhetoric, design studies, design history, InfoVis, and digital media studies. Based on the theories and vocabularies from the critical review, I articulated the new rhetoric of data visualization allowed by computation. In doing so, I partially answered the first research question—what are the influences of computation on visualization? To be specific, how does computation affect the *rhetoric* and the *aesthetics* of visualization? In the following chapter, I focus on the aesthetics of data visualization.

Chapter 4

The aesthetics of data visualization

In parallel with the first focus on rhetoric, this chapter investigates the aesthetics of data visualization. To address the problem space again, same as rhetoric, the notion of *the aesthetics of visualization* has no standard definition or vocabulary among the related fields' researchers and practitioners. Simply, everybody has his or her own idea when it comes to aesthetics. Aesthetics is a broad term that can be used to imply the mere surface of a thing to an immense inquiry for philosophy of art. These philosophical contemplations explore the complex situations of artwork making and materials, and the relation with external contexts and audiences. In this chaotic and discordant situation, as a first robust attempt to discuss aesthetics of data visualization in digital media studies and design research, this dissertation has the obligation to identify the scope of aesthetics for the research of data visualization. The first two sections are the results of literature review and my own synthesis to this job. Next, I articulate the roots of aesthetics of visualization from modern graphic design in terms of both formal resemblance and inherited philosophy, or rationalism. Finally, same as the previous chapter, I discuss the new aesthetics of data visualization drawn by computation.

4.1. Current views on aesthetics

The first step to define the language used to understand the aesthetics of data visualization would be to analyze what InfoVis researchers, computer graphics pioneers, and HCI/interaction designers have said. While reviewing their approaches, I reveal the

limited or missing aspects in the discussion of aesthetics for data visualization research. I also review several important theories on aesthetics by new media scholars that relate aesthetics as philosophical concept to the embodied phenomena in digital environments.

4.1.1. Limited understanding of aesthetics in InfoVis

With its focus on functionality and accurately portraying data to viewers, InfoVis still maintains aesthetics as a topic of only peripheral interest in the mainstream InfoVis research community. As evidence, searching for the keyword "aesthetics" in an annual journal *IEEE Transactions on Visualization and Computer Graphics* spanning from 1995 to 2012 returns only twenty-six articles.

Aesthetics often refers to *style* that explains a variety of expressive choice of individual visual elements in an identical visualization techniques. For example, Vande Moere and his colleagues designed three different styles (analytical style, magazine style, artistic style) for one identical scatterplot view and evaluated how each style helps users gain insights (Vande Moere, Tomitsch, Wimmer, Christoph, & Grechenig, 2012). This classification of style is based on his former research on the model of Information Aesthetics (Lau & Vande Moere, 2007). This model identifies aesthetics as a standard or axis to categorize and relate various visualization techniques. Thus, according to this model, a specific visualization technique can be considered "less aesthetic" than another.

Some of these articles deal with aesthetics as "pretty appearance" or a synonym for "visually pleasing" when introducing new visualization techniques. When InfoVis researchers suggest new algorithms for graphs, they now tend to put more emphasis on the visually pleasing appearance through unique forms or the properties of colors. For example, as presented earlier (Figure 11), Byron and Wattenberg (2008) describe the role

of aesthetics in the appeal of visualization. In their case, the aesthetic quality is drawn on the unique look of the visualization that is different from standard statistical graphs. When analyzing the readers' reaction to the visualizations exhibited on *The New York Times* website, they acknowledge an important role of aesthetics to engage with the visualization *despite* the possible conflict with the need for legibility.

The understandings of "aesthetics" found in other articles are also distant from what philosophers or even designers regard the term as fulfilling. What researchers from computer science and InfoVis mean by aesthetics is mostly only "artistic" in a very limited manner; the situations that the appearance of screen looks like an artwork, specifically abstract painting. For them, art means only "fine art," no other forms of visual media that could also be considered tasteful, and they conclude that simply mimicking work of famous fine art into InfoVis system satisfies aesthetics. For example, Fogarty, Forlizzi, and Hudson (2001) proposed the Kandinsky system. They first focus on making the system aesthetically interesting, then add a perceived bonus of conveying information. In their arguments, this system is aesthetic (i.e., artistic) because it borrows the visual form of Kandinsky's artwork. In a similar fashion, an ambient information system is claimed to be aesthetic because it adopts the form of Mondrian's abstract paintings (Skog, Ljungblad, & Holmquist, 2003).

In classifying ambient information system, Pousman and Stasko (2006) suggest a one-dimensional "aesthetic emphasis." Their view on aesthetics is also of a formal quality portrayed through sculptural or artistic conventions that might ignore information communication ability. In sum, aesthetics has been considered in the meaning of "artistic,"

but with a confined boundary; researchers simply equate “aesthetic visualization” with “looks like an abstract artwork.”

This narrow view of aesthetics, as a substitute for style or attractiveness, is often followed by “an evaluation on aesthetics.” Since aesthetics (even in the meaning of style) is still a small topic in InfoVis and subordinate to the primary goal of Infovis—functionality, existing attempts in aesthetics try to quantify human perception and satisfaction with interactive systems. Numerous efforts support the argument that better visual design leads to better functionality, usability, and efficiency (Tractinsky, Katz, & Ikar, 2000; Cawthon & Vande Moere, 2007).

Many researchers in InfoVis consider that aesthetics is a concept that is independent from or even opposite of objective quality or functionality. Their attitude toward aesthetics is still that it is a second priority following efficiency or legibility, especially for task-supporting systems. This dichotomous perspective is also found in Kosara’s criticism on visualization (Kosara, 2007). In his argument, aesthetics implies the visual appearance of the system and can be an axis used to categorize visualizations; aesthetics matters as a quality of “artistic visualization,” and it is contrasted from the utilitarian properties of “pragmatic visualization.”

Reviewing a wide range of research on aesthetics in InfoVis allows us to conclude about that in current research: 1) aesthetics usually concerns the surface of the system, 2) the realization of aesthetics is equivalent to making abstract artwork-like look or decoration, and 3) aesthetics is unrelated or distant from, and even may hinder, the core efficiency of a system.

4.1.2. Early perspectives from computer graphics

The techniques of visual representations of continuous data were common by the end of the 19th century. They include histograms, line graphs, and time-series plots and contour plots. However they became more popular after the 1960s when computers were used for the automatic creation of 2D and 3D graphics. Mathematically generated smooth curves such as NURBS (Non Uniform Rational Basis Spline) became the standard way to represent smooth surfaces in computer graphic software (Manovich & Douglass, n.d.) which is a common form in scientific visualization. In this context, for the purpose of investigating the influence of computing on the aesthetics of data visualization, it would be meaningful to review the early endeavors to build theoretical background within computer-based art when the modern computing technology started to flourish.

In the 1960s, Max Bense developed a system of information aesthetics that understands aesthetic objects as signs framed within Shannon's purely technical communication model. Employing Norbert Wiener's cybernetics as a model for the process of art production, consumption, and criticism, he aimed to create a rational aesthetics based on a scientific base, not from a subjective speculation (Klütsch, 2007). Bense's information aesthetics as "process and order" led to the statistical analysis and mathematical value of information in the 60's and 70's. Aesthetics as information processing, or generative aesthetics, connected aesthetic theory with formal computer graphics (Klütsch, 2007). These mathematical approaches to seek the law of aesthetics seem in alignment with the rising technology of computing at that time. Computer artists, who had been in fact trained formally as mathematicians, wanted to follow a new way for art production: principles of scientific experiments rather than traditional artists' trial-

and-error. In the spectrum between order and disorder, they tested pseudo-random number generating algorithms for experimental drawings that are composed of repetitive and mutated lines or geometrical forms.

Klütsch (2007) concludes that these approaches by Bense and other mathematician-artists (or computer artists) are critical since they are the example of linking "The Two Cultures" that are humanities and natural sciences. However I argue that both of their theories for aesthetics and the artworks fail as examples to connect the two cultures. First, as discussed earlier, the approach to measure aesthetics through a mathematical equation is not the appropriate way to appreciate artwork or design artifacts. Second, although it is understandable that computer artists with mathematics background were fascinated with the new technology, they focused only on the new production methods of the artwork. The neglected aspects are as follows: 1) They did not critique the visual forms that were only possible to be created with computers. 2) Viewers' experiences occurring in the interaction with the artwork were ignored, in terms of either emotion/affection or utility. 3) Moreover, there is no discussion on how the technology affects the holistic aesthetics through the situated communication among the artists, the artifacts, and the viewers.

4.1.3. Aesthetics with instrumental concerns in HCI

The focus of aesthetics in HCI and interaction design deviates to some extent from aesthetics in fine art. When aesthetics comes into play as art critique, it does not concern the instrumental values of artworks. However, approaches in the practice of *design* stress that aesthetics is not about immediate visual impression, but is related to the use of the interactive system. Not dissimilar from its current state in InfoVis, aesthetics

formerly was considered marginal in the traditional HCI research; functionality has been the primary requirement in designing interactive digital artifacts in most cases.

Not much different from the InfoVis field, aesthetics used to be trivial in the traditional Human-Computer HCI reseach. However, with the current growing interest in and influence of design, researchers in the HCI community investigate aesthetics as a sole theoretical theme. What is noticeable in this lane of research is that aesthetics has emerged as an alternative concept or terminology for discussing the expansion of the focus of HCI reseach, from work-oriented systems to systems for leisure, education, and games (J. Bardzell, 2009; Udsen & Jørgensen, 2005; Petersen, Iversen, Krogh, & Ludvigsen, 2004; Locher, Overbeeke & Wensveen, 2010). These theories help us understand what aspects of aesthetics as a philosophical discipline are employed in interaction design and HCI research.

The direction of research on aesthetics in HCI was once well discussed by Udsen and Jørgensen (2005). They argue that aesthetics brings an enhanced analytical foundation to IT design and research beyond traditional user-oriented principles of HCI. They classify this namely “aesthetic turn” in HCI research into four approaches: cultural, functionalist, experience-based, and techno-futurist. All investigate the new instrumental opportunities driven by digital technology.

Cultural approach has its academic tradition in humanities and new media studies. Laurel’s (1991) metaphor of user interface as theoretical performance, Bolter and Grusin’s (1999) remediation, and Manovich’s (2001) cultural interface are the eminent theories among cultural approaches. In cultural approach, interface is an aesthetic form and a cultural artifact that is capable of evoking human emotions, experience, and

reflection. As argued earlier in this thesis, I also consider visualization as not merely screen-based images of data representation, but also a cultural interface that works as a rhetorical means.

The cultural approach in new media studies mostly deals with the history or paradigm of computing technology with a special focus on interface. The aesthetics of interface is often drawn on the tension of transparency and experiences or reflectivity. For instance, the mirror-windows metaphor of interface design or interactive art, which Bolter and Gromala (2000) suggested, also deals with the new functions of digital technology.

Functionalist approach is based on the attempt to quantify human perception and satisfaction with interactive systems. The experiments conducted by researchers support arguments such as “beautiful interfaces support traditional usability” and “aesthetic appeal of simplicity increases the perception of trust.” The common foundation of these arguments is Don Norman’s notion of emotional design, best summarized as “both useful and beautiful things work better.” This approach is certainly a supportive ground when engineers request designers to prove scientific evidences to obey specific design choices. However, functionalist approach is not adequately appropriate to aesthetic domains of beauty, emotions, or taste.

Interaction designers who seek new ways of communicating immaterial messages and experiences through digital artifacts primarily shape *experience-based approach*. In this approach, such digital artifacts are not necessarily useful nor have pre-defined purpose, but rather possess exploratory spaces for “aesthetic interaction.” This approach is the most similar to the methods in design research. The experience-based approach

provokes the hardwired views for electronic devices, suggesting disparate angles to the aesthetics of post-functionalistic objects. Gaver's ambiguity (Gaver, Beaver, & Benford, 2003) and Dunn's (1999) para-functionality appeal to this approach.

The final, *techno-futurist approach* is the least well-defined of all and based on philosophical perspectives, mainly phenomenology for ubiquitous computing environments. Paul Dourish (2001) is the leading researcher who considers embodiment as an expression of our basic bodily relation to digital interfaces. Researchers in this area do not see technical objects as tools for specific uses, instead they are concerned with how technology manifests itself in everyday life and constructs meaningful presence.

Pragmatic aesthetics, originally a subject of contemporary philosophy, is what interaction design and HCI researchers adopt for the more explicit notion of "aesthetics of use" (Petersen et al., 2004). In dealing with interactive systems, their focus is the instrumentality of aesthetics. The instrumentality is based on the social-cultural contexts of the human appropriation of the artifacts (linked to the cultural approach). More importantly, what they mean by "instrumentality" in pragmatist's aesthetics is "the ability to surprise and provoke and to move the subject to a new insight of the world" (linked to the experience-based approach). To summarize, the tight connection to the context, use, and instrumentality creates aesthetic interaction. It is "thought-provoking and encourages people to think differently about the encountered interactive system, what they do and how they might be used differently to serve differentiated goals."

A more practical approach to designing aesthetic interaction was introduced as "interaction gestalt" (Lim, Stolterman, Jung & Donaldson, 2007). Indicating the lack of

discussion on the practical guide of aesthetics in designing artifacts, they suggest a framework that interaction designers can apply to their screen-based or tangible artifacts.

Bardzell's (2009) more theoretical discussion emphasizes the philosophical treatment of culturally implicated interaction design. While he suggests that aesthetics and critical theory from cultural studies should be applied to interaction design, in particular for the deconstruction of the user and the artifact, he stresses the methods for interaction design. In other words, he explicitly criticizes employing artistic methods to computing activities and quantitatively evaluating the aesthetics of interface. He is also clearly against the narrow notion of aesthetics of interaction in the decorative elements that adorn interface. In contrast to the other HCI researchers who focus on one philosophical/aesthetic theory and attempt to apply it to real interactive systems, Bardzell suggests a broader view: analytic aesthetics (for positivist and empiricist approaches to interaction), hermeneutic aesthetics (for phenomenological orientation for human-centered interaction), and pragmatic aesthetics (for coupling pragmatism and experience design) all have potential to be the theoretical grounds for interaction aesthetics.

4.1.4. New media theories for aesthetics

In the late 90's, scholars with backgrounds in traditional disciplines attempted to identify the characteristics of digital media and the type of environment that enabled the emergence of new types of media. They did not particularly define the new aesthetics of new media, but understanding and applying the new media theories to specific genres is a typical way to analyze the diverse phenomena surrounding the media. Here I introduce several key new media theories that I will use later for the analysis of visualization examples. I also warn of the limitations of theories when employed in this thesis.

While exploring the computer as an expressive medium for interactive narrative beyond the focus on the crystallization of new technologies, Janet Murray (1997) introduces the four essential properties of digital environments—procedural, participatory, spatial, and encyclopedic.

- Digital environments as *procedural* refers to how they are identified with a series of rules that describe any process. Procedural environments are appealing for storytelling because we can write rules as an interpretation of the world.
- With the procedural property, *participatory* environment characterizes what we mean by "computers are interactive."
- The *spatial* quality is created by the interactive process of navigation. According to a user's input, screen display changes.
- The *encyclopedic* property refers to a digital environment that is capable of representing enormous quantities of information in digital forms with a wealth of detail.

She also discusses the aesthetics of digital media drawn on these four characteristics. To her, aesthetics refers to "the pleasure of digital environments" and has three characteristics—*immersion*, *agency*, and *transformation*. Pleasure means an intrinsic and cognitive satisfaction with the working of the digital system, not the narrow definition of "having fun." Immersion is created in the exploration of the media, which is closely tied to the spatial and encyclopedic properties of the digital environment. In comparison, sense of agency is a phenomenon that happens within the procedural and participatory circumstances.

Agency is “the satisfying power to take meaningful action and see the results of our decisions and choices.” Moreover, “we expect to feel agency on the computer when we double-click on a file and see it open before us or when we enter numbers in a spreadsheet and see the totals readjust” (Murray, 1997, p. 126). Agency is not what is automatically expected or experienced within a narrative medium, but acquired from users’ participation in the medium. What is different in computer-based interactions is that the virtual world we encounter is dynamically altered by our participation. For instance, a word-processing task requires a certain series of structured actions, and users will see appropriate responses as a result of controlling the medium used for the task; this is the feeling of agency.

Manovich (2001) suggests the five principles of new media: numerical representation, modularity, automation, variability, and cultural transcoding.

- *Numerical presentation* means that new media object can be described mathematically, and it is subject to algorithmic manipulation. Continuous data (he refers to data as a larger meaning of cultural objects) is coverted to numerical representation through digitization composed of sampling and quantification.
- The principle of *modality* explains the fractal structure of new media. Media elements are assembled into larger-scale objects while maintaining their separate identities. For instance, hundreds of still images can be combined into a movie with video editing software. This principle affords the ability to delete, substitute, or add new objects when modifying electronic files or programming code.

- With the numerical coding of media (principle 1), it allows the *automation* of many operations in media creation, manipulation, and access. Automation includes both low-level types, such as labor-saving macros in software, and high-level ones, such as Artificial Intelligence and game engine design.
- *Variability* means the situation that a new media object is not fixed but able to exist in different, potentially infinite versions. This is a consequence of the first principle (numerical representation) and the second (modurality). It explains that the database of a cultural form in its own right can be represented in various, variable, and customizable forms. In addition, Manovich stresses that "a number of different interfaces can be created from the same data."
- The last principle, *cultural transcoding* refers to the cultural data (cultural layer) that is transformed into computerized data (computer layer.) Both layers influence each other; human-computer interface resembles the interface of older media machines and cultural technology (e.g., web sites adapt the interface of printed pages); a new technology such as hypermedia can be understood as one cultural effect separate from algorithms or data structures (Manovich, 2001, pp. 27-48).

Manovich believes that contemporary digital technologies are reminiscent of media techniques from the modernist era. "Aesthetics of early information culture" results from the convergence of historical cultural conventions and the conventions of HCI. However, digital manipulation allows the visual aesthetics of the earlier technology

to undergo a fundamental change. For example, Moholy-Nagy's photomontage, which became a basic technique of modern visual culture, has multi-image composites using transparency, blur, and colorization that are easily available on image editing software, such as Adobe Photoshop (Manovich, 2003, p. 21).

Through the transformation of data driven by digital technology, the material properties of a new way of representation can create new aesthetic possibility. Based on these new media theories by Murray and Manovich, I will discuss the new aesthetics of computational data visualization in the rest of this chapter. In effect, how have the principles of new media offered new opportunities for producing, exhibiting, and sharing of visualization?

"Aesthetics" is a grand word and there is no shared understanding of aesthetics of visualization among theorists and practitioners. Thus, in this section, I selected the most proximate fields to visualization to review what people in these fields—InfoVis researchers, early computer graphic artists, HCI researchers, and new media theories—have discussed regarding aesthetics. With these presented concepts, I define the aesthetics of data visualization in the following section.

4.2. Defining aesthetics for data visualization research

In this section I suggest three new perspectives to view aesthetics of data visualization based on the learning from the previous literature review: the limitations of aesthetic notions in InfoVis and early computer graphic art, the extended views on the aesthetics of interactive systems, and the characterization of the digital environment and media of HCI and designer researchers. First, the aesthetics of data visualization can be scrutinized by focusing on the traditional HCI-driven perception of beauty: *look-and-feel*.

Second, beyond the surface visuals that tie in to functionality, the aesthetics of visualization can be elevated to the level of *communication*, a holistic experience among the maker, artifact, and appreciator resulting in *trustworthiness*. Another angle to view aesthetics is *situated aesthetics*. Originally from conceptual art, situated aesthetics implies the cultural references in the design of visualizations and the rhetorical interpretation of audiences.

A design philosopher and creator, Leonard Koren (2010) scrutinizes "aesthetic" and "aesthetics" as they are used in everyday conversations, in the media, and in critical literary in the fields of art and design criticism, history, philosophy, and anthropology. He introduces ten definitions of aesthetics—*appearance*, *style*, *taste*, *philosophy of art*, *thesis or exegesis* (organization of thoughts on artwork or design artifacts in verbal or written form), *artistic*, *beauty*, *beautification* (of human body), *cognitive mode*, and *language* (ways of communication of aesthetics in all previous definitions.) These definitions provide a large context in which the term can be used, and in fact, several definitions among these have been used to discuss aesthetics in visualization design and research. I will also adopt these terms for identifying three aspects of aesthetics for data visualization research. However, these definitions as a series of discrete words cannot be used to fully understand the aesthetics of visualization as a visual medium that has its unique materiality and forms for analytic and presentation purposes.

4.2.1. Look-and-feel linking beauty and utility

At the most shallow level of meaning, aesthetics refers to only the surface *appearance*, such as decorative veneers or an overlay applied to a more substantial core substrate. The second meaning by Koren, *style* is a perceptually cohesive organization of

sensory qualities, as used in “modernist” or “rococo” style. Last, *taste* means the ability to perceive and distinguish artistic and stylistic features of things, which is later used to make value judgments.

As practical interface design guidelines instruct, “look-and-feel” means the aspects of graphic design in designing mostly for two-dimensional screens: (i.e. websites, mobile phones, and the surface displays of home appliances.) In designing the “look” of user interfaces, the talent of individual graphic designers is the most crucial, as it decides the beauty, craftsmanship, and fine finishing of visual elements such as icons, text, and layout. I consider the “look” part of interaction design a matter of “aesthetics.” In this meaning, aesthetics is close to the following cases among Koren’s ten definitions: appearance (saying this visualization is pretty or nice to look at) and style (ManyEyes and *The New York Times* interactive graphs have their own color schemes and font selections). Look-and-feel could also be a concern of taste (i.e. “The default color combination of charts on Excel 97 doesn’t fit my aesthetics.”)

I also argue that look-and-feel is not merely the matter of appearance, style or taste that implies only the impression of the surface. As HCI and interaction designers have discussed, look-and-feel can cover the instrumental value of the interface. Users of interactive systems do not entirely disconnect the beauty of appearance and the utilitarian aspects of the interface system. The word “feel” is not only about the visceral responses to the appearance, but also about the perception of the usefulness and ease-of-use. In other words, “feel” can be related to the intuitive and even unconscious decisions of usability when users first encounter the interface. To revisit the functionalist approaches

to aesthetics, a visually appealing system can endow itself with a sense of satisfying or even guaranteed quality functionality.

4.2.2. Aesthetic communication for trustworthiness

When I apply the concept of look-and-feel to visualization, I do not fully include users' actions and the consequent responses that display. The animation of the special elements of the visualization is the output in the process of interaction between the media and the user. Although the visual feedback arouses favorable impression at a surface level, such interaction brings out the intrinsic satisfaction regarding the use of the media. This deeper and more complex phenomena than look-and-feel can be explained as *pleasure*, which is one angle to view the aesthetics of digital media. Considering the utilitarian nature of visualization, *agency* is the most suitable vocabulary that can be related to *aesthetic communication*.

Iseminger (2010) defines aesthetic communication as the intentional activity of someone's designing and making an artifact that someone else appreciates later. This communication typically involves three elements: a designer and maker, an artifact made for appreciation, and an appreciator. What makes this communication aesthetical is the understanding that the thing produced is *appreciated*. He stresses that these three elements (creator, artifact, audience) should be connected with appreciation to create aesthetic communication. Iseminger defines appreciation as "finding the experiencing of a state of affairs to be valuable in itself." Experiencing a state of affairs is a matter of having direct knowledge of what that state of affairs obtains, which is an epistemic value rather than a phenomenological one. It is not merely sensory but involves conceptual capacities depending on prior knowledge. Experiencing is in contrast with finding value,

since finding something valuable, in itself or instrumentally, is a doxastic concept that is a matter of belief not truth. Yet experiencing something with value in itself is a way of appreciation, but not always enjoyment. Not only physical objects but also events or processes can be appreciated. Moreover, semantic experiences such as grasping the fact that a proof works or feeling the suspense in a well-plotted story can be appreciated in the epistemic sense (Iseminger, 2010, pp. 62-72).

The interactive features of visualization still mainly focus on the functional assistant for investigating the represented data. The actions that users can take are limited to mouse control, and the feedback is the expected change of image within a short time interval. Visualizations may not provide a sense of immersion, which is brought about through the spatial and encyclopedic nature of digital media, as much as other narrative-rich mediums such as simulation video games. Moreover, while devising the interactivity of visualizations, designers do not integrate complex rewards or penalty systems. However, the pleasure of experiencing visualization is obtained through the procedural and participatory features of interactive visualizations and the conversation resulting as *agency* creates aesthetic communication.

With the concepts from the theories above, I argue that “appreciation” and “agency” are specifically understood as *trustworthiness* when they are applied to the aesthetics of InfoVis. Trustworthiness does not mean only the trust in functionality, which is pursued through a narrower sense of aesthetics, look-and-feel. When people use other software, the designers of the system are anonymous and their presence in and around the system rarely appears. However, the influence of designers is more immediate when people are interacting with presentational visualizations. The designer encodes her

messages into visualizations and the user becomes obliged to decode the designer's intention as he feels the tension with the designer. Thus, I consider trustworthiness as an outcome of aesthetic communication, because the believable representation of data without arousing users' suspicion is the ultimate pursue of visualization design. Unlike other task-support software whose functionality is the core pat of the system, InfoVis should build trustworthiness as the primary goal of communication and the evidence of satisfaction.

4.2.3. Situated aesthetics

The last focus in my definition of aesthetics concerns the circumstances that surround the communication between the system and the user. In HCI theories influenced by social sciences, especially anthropology, the concept of "situated" refers to the divergent way of using, understanding, and appropriating systems depending on cultural backgrounds. A notable work in this agenda is done by Suchman (2006), who contrasts two views on purposeful action: plan and situated action. While people make plans prior to action, but it chances according to circumstances; actions are situated in the context of practice and create informal knowledge.

Situational Aesthetics was first introduced by a conceptual artist, Victor Burgin (1969). In contrast to the classical notion of aesthetics, situational aesthetics takes its essential form in messages rather than in the materials of artwork. The messages focus on the conditions under which objects are perceived so that the art is placed within the linguistic infrastructure. Art as message does not exist as an individual object, but works as "software" that consists of sets of conditions that generate objects. This perspective is

linked to a way of art critique, conceptualism that puts priority on concepts rather than artistic execution.

Hall (2008) labeled artistic practices in visualization, due to its stronger emphasis of contextual elements, as "critical visualization," which is a meta-perspective and theoretical approach that is comparative with technological and scientific approaches in visualization research and practices. As he acknowledges that the line between a mode of technological and scientific inquiry and a form of figurative expression has been blurred, Hall argues that, "the art of visualization can be seen as an important critical counterpoint to the technological and scientific view." He also expands the confined view of visualization art as the production of self-rationalized aesthetic and asserts that visualizations are forced by historical events, local stories, economic and legislative conditions, and political interests. In other words, visualization is not a mere creative process concerned with the finished artifact but the framing, gathering, and arraying of data. Then visualization becomes *a critical practice*, "sizing up and reformulating a terrain of knowledge as well as experimenting with new and alternative forms." *Critical visualization stresses the contextualization of data and the representation as a cultural product.*

What is important about situated aesthetics is that the aesthetic is highly cultural, thus meant to be rhetorical. In addition to the previous two definitions that focus on the link of superficial beauty, utility, and the interactivity within the ecosystem around the media, situated aesthetics is another important angle to understand the aesthetics of cultural artifacts.

Proposing "speculative computing," whose emphasis is the production of humanities-based tools within a digital context, Drucker argues that these tools create aesthetic provocations that have unpredictable results in visual, verbal and textual forms (Drucker, 2009, p. 25). Interpretation of the results born out of using a humanities approach is a concern of *aesthesis*. Drucker uses the term aesthesis as a rubric under which aesthetics provides situated knowledge and the embodied expressions of experiences. She explains aesthesis as follows:

> "Aesthesis focuses on the generative perception and cognitive production of information and its material expressions in any medium. Aesthesis is distinct from the analysis of representation, but is dependent on recognition of the cultural and historical characteristics of visual forms, their materiality, and the rhetorical assumptions built into formal expressions of knowledge. In the context of digital activity, the examination of aesthetic properties includes discussion of code and its specific materiality, modes of production that are integral to digital media (interactivity, intersubjectivity, iterative and algorithmic principles of production), models and modeling processes, and the specific ideology of virtual artifacts. "

She continues the discussion on aesthesis in regards to the rising problems in current studies and practices of information visualization, or "the way of graphical forms of knowledge work in digital environments."

> "(T)he connection between "information" and "visualization" is so readily enabled by digital instruments. (…) The engineering sensibility that under girds most information visualization seems to take scant interest in the rhetorical and ideological force of its operation. Exposing the ideology of graphical forms is crucial to our contemporary condition, extending traditional critical discussions of these issues from the study of visual language."

Drucker argues that graphical arrangements such as diagrams, charts, and other structuring forms have been discussed in connection with cultural and social issues and the materiality of aesthetic works. According to her, "(a)ttention to materiality has too

often assumed a literal and mechanical reading of formal features rather than an analysis of material codes as provocations for cognitive processing."

Aesthesis provides a counterpoint to mathesis, the idea that human thoughts might be represented in a formal language. In other words, subjectivity, individual expression, and specificity challenge the cultural authority of alignment, totalization, and systematic approaches to knowledge. Drucker stresses this argument states "acknowledging the difference between subjective knowledge (situated and partial) and objective knowledge (transcendent and totalizing) carries a political as well as aesthetic charge (Drucker, 2009, p. 129)." In sum, aesthetics means more than simply what is seen on the surface, the form (encompassing visualization technique,) choice of colors and typography, and even interactivity can provoke rhetorical intentions and lead to situated interpretation.

In this section, I identified three new perspectives to view aesthetics of data visualization: beauty and utility as a connected aesthetics, aesthetic communication as pleasure in digital environment, and situated aesthetics as cultural interpretation. With these definitions, I will discuss the aesthetics of data visualization in the following sections. I find the roots of contemporary computational visualization from modern graphic design that advocates simple and minimal visual aesthetics built on rationalism. Next, I focus on the new aesthetics of data visualization driven by computation.

4.3. Aesthetic roots in modern graphic design

As discussed earlier, in InfoVis, aesthetics is not treated as a philosophical subject, but a concern for surface. Even in this restricted manner, there exist limits (extremely narrow meanings of aesthetics) and neglected aspects (no attempts to find the formal tradition of visualization techniques). I argue that investigating the roots of aesthetics is

important because knowing the underlying philosophy and languages that brought visual forms into history provides a skeleton from which novel forms can be created.

To find these roots, I start with looking into the pre-modern graphic design era, from which I argue the archetypes of contemporary data visualization originated. Then I trace the historical background from the 20th century modern graphic design that has many similarities in principles of composing two-dimensional visual media. Next, I argue for the rationale beyond the formal tie between modern graphic design and data visualization. I connect how the principles of modern graphic design can be applied to the design principles and the subsequent visual forms of contemporary data visualization. Last, I present several evidences to link the visual resemblance between modern graphic design and current data visualization by connecting the formal traits of data visualization to the aesthetics and principles of modern graphic design and early data graphics.

4.3.1. Formalization of modern visual language

Modern art movements such as Cubism, Russian Constructivism, and De Stijl influenced the 20th century graphic design. The visual forms of these movements, which are featured as geometric abstraction and flat, hard-edged forms, flourished in the era of the Bauhaus, and more rigidly later in the International Typographic Styles (Swiss Design). I articulate the visual principles and techniques as well as the founding philosophy of these trends in the 20th century modern graphic design.

4.3.1.1 Early data graphics

When considering the principles of information design, one tends to think it is the legacy of the 20th century modern arts and design, because it features clarity for effective communication, the economical use of compositional elements and colors, and the grid-

based layout. However, sufficient evidences tell us that we can trace the history of information design and visualization to the 17th century at the latest from the fields of mathematics and natural sciences (Friendly, 2009; Pohancenik 2010). At that time, professionals whom we today call graphic designers did not craft these visual representations, so the application of aesthetics as visual appeal was not a crucial factor. However, the creators of the early data graphics already utilized primitive visualization elements such as line graphs, bar charts, and pie charts before the late 19th and early 20th century, a time when the visual aesthetics of visualizations were impacted by the newfound principles of modern graphic design.

We witness many examples of visual representation of numerical data in scientific publications prior to the modern era. Those visualization techniques started to be used in the 18th century. Meteorologist Nicolaus Samuel Cruquius introduced abstract line graphs in 1724, and engineer William Playfair devised bar graphs and pie charts in 1786 and 1801 respectively (Figure 35) (Friendly & Denis, 2008).

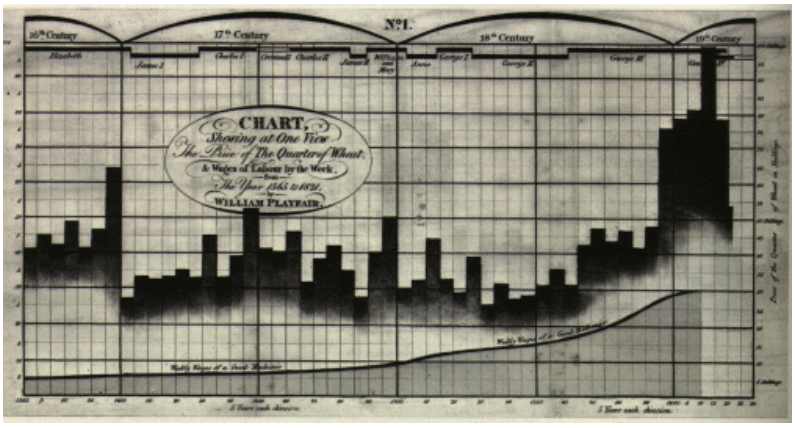

Figure 35. Playfair's bar and line chart on the price of wheat and wages (http://www.datavis.ca/milestones/index.php?group=1700s)

Outside of natural scientific fields, geometric and demographic data have been transformed into graphical variables that are commonly found in visualization techniques.

In his text “The Commercial and Political Atlas,” Playfair used a series of forty-four charts of time-series data that sought to explain the increasingly complicated economy of the day (Kostelnick, 2004). Focusing on the infographics in newspapers, which he defines as the craft of telling news stories using the tools of information design, illustration, cartography, and photography, Cairo (2005) considers that the early eighteenth century is the first time when the infographics emerged. His example is the one published in 1702 by *The Daily Courant* in England, in which maps, charts, and visual explanations are all linked, unlike in older maps.

4.3.1.2 Bauhaus

In the spirit of an avant-garde movement, the Bauhaus, first established in 1919, became the legendary institutions for art and design pedagogy. The founder Walter Gropius extended the aim of Arts and Crafts studies and emphasized that all architects, painters, and sculptors should be integrated and go to back to the crafts. Following his manifesto, the education focused on developing proficiency in crafts. However, the school’s individualistic crafts-based Expressionist style, which was represented by Paul Klee, eventually gave way to Constructivism. The Bauhaus came to share the Constructivists’ outlook. With additional inspiration from Dadaism, the spatial aesthetics of geometrical planes influenced New Typography (Hollis, 2006. pp. 24-25).

When Laszlo Moholy-Nagy’s typographic workshop started a few years later, there was a shift from “Arts and Crafts” to art and industry. Particularly in typography, he contributed an important statement: “[T]ypography is a tool of communication. It must be communication in its most intense form. The emphasis must be on absolute clarity… Legibility—communication must never be impaired by an a priori aesthetics. Letters

must never be forced into a preconceived framework, for instance a square" (Megg, 1992, p. 291). Through systematic curricula, the Bauhaus shaped graphic design as a discipline and a profession. The institutionalized forms were in favor of a pursuit of "universal" principles and systems. Students trained at Moholy-Nagy's Bauhaus, including Max Bill and Theo Ballmer, extended the principles of the Bauhaus style and publicized a functional and systematic approach.

One famous typographer and a graphic designer influenced by the Bauhaus is Jan Tschichold. In his seminal book, "new typography (die neue typographie) (1928)" he demands the elegance of sans serif fonts, and favored non-centered and asymmetrical layout design (Tschichold, 2006). His design was distinguished by bold diagonal titles and typographic minimalism capable of reducing a page to essential-seeming elements in a delicate but dynamic balance (Figure 36) (Drucker & McVarish, 2009, p. 206). After World War II, he abandoned his novel typography notions, and instead designed serif-fonts. Nevertheless his pre-war typography principles are still influential and considered fundamental teachings in art and design schools.

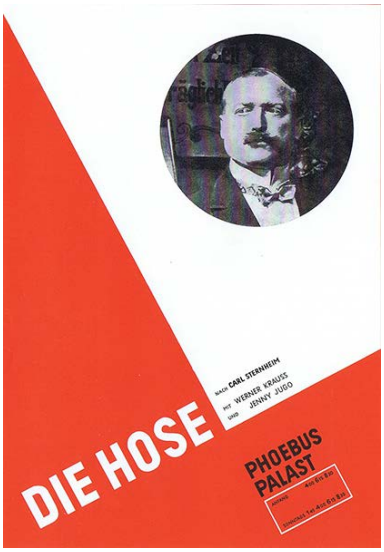

Figure 36. Jan Tschichold, poster, 1927. (http://www.josye-utick.com/?p=122)

4.3.1.3 International Typographic Style

The 1950s witnessed an emerging design style from Switzerland and Germany, which was called Swiss design or the International Typographic Style. The International Typographic Style is rooted from de Stijl and Bauhaus, and drew selectively on principles of the new typography advocated before the war by Jan Tschichold (Drucker & McVarish, 2009, p. 265).

Architects and graphic designers who had studied at Bauhaus expressed the formal language through their artworks. For example, Max Bill, a well-known Swiss artist of the 20th century, enjoyed effective forms through geometry and simple spatial relations. He worked by starting with a sketch of a rectangle as an entire frame, dividing the space with horizontal, vertical, and diagonal lines, and then filling the divisions with round elements, which resulted in positive-negative space contrast (Fleischmann & Cullars, 2001) He is also the first director of Ulm School of Design that was initially created in the tradition of Bauhaus. Graphic designer and typographer Wolfgang Weingart, whose work is categorized as Swiss style, describes in his book how the Swiss style has developed at Basel School of Design, where the style flourished with its prominent teachers such as Emil Ruder and Armin Hoffmann.

International Typographic Style is characterized by underlying grid structures, asymmetrical layouts, sans serif type, “objective” photography, geometric forms, and an almost total absence of decoration or illustration. It sometimes is accompanied with photomontage techniques. The clean and unfussy directness allowed a neutral, universal basis for rational communication, and also served to erase ethnic, cultural, economic, and political differences (Drucker & McVarish, 2009, pp. 263-264).

A key graphic designer of the International Typographic Style, Josef Müller-Brockmann stressed a highly logical and grid-based system of layout. Proportions and harmony were important for efficiency and functionality, which was delivered through the impassive presence of underlying structures and the rational organization of contents. In his book "Grid Systems in Graphic Design," which he wrote for graphic designers who operate two-dimensional spaces, Müller-Brockmann introduced the notion that that with a grid system a designer was better fitted to find a solution to his or her design problems. His grid system was based on a number of columns, typically two to four. He set the optimal size of fonts for the main text and the readable spacing between paragraphs so he could calculate the number of lines of text in one column. In addition, he sketched out horizontal lines crossing the columns to create "fields." He created variations of layouts with text, illustrations and photos through merging the fields. The figure below illustrates the case of 20 (4 by 5) grid fields (Figure 37). While he discussed functional and logical problem solving, he also stressed the balance between the scientific aspects of readable printing and the visual aesthetics of formatting. His point was that functional rigidity can be visual pleasing (Müller-Brockmann, 2001).

The standards of classical typography were still praised until early seventies. Jan Tshichold confirms his standpoint saying:

> Good typography is not loud. A reasonably applied and readable type style is the first ingredient of good composition. Today, asymmetric composition is certainly feasible, however, typography is intrinsically symmetrical. A text block without indents is unclear. Indents help the reader by reinforcing the logical order of the text. The best typography is invisible to the reader and serves to transmit the thoughts and intent of the author. Beautiful text, a text well-composed, is risible. One of the highest virtues of good typography is its subtle elegance. It is not the duty of the typographer to consciously display or emulate the style of current trends, nor to reflect the

spirit of the times. Typography must be itself. It must be pleasing to the eye and not tiring. Good typography has absolutely nothing to do with remarkable or exotic type styles. This is the opinion of amateurs. The essence of letter-form is not modernity, but readability.' (Weingart, 2000, pp. 109-112).

This impenetrable dogma was provocative to young designers, even those who were educated by Bauhaus-influenced designers. In dealing with two-dimensional spaces, designers in the trend of Swiss Design performed typography and geometry-based experiments that break the traditional design rules. Yet they still exert their creativity in the realm of aesthetics of Swiss Design from Tschichold through Ruder. For example, although designers assign different letter spacing in one phrase, they repeat the use of a singular typeface and arrange the text in a geometrical layout.

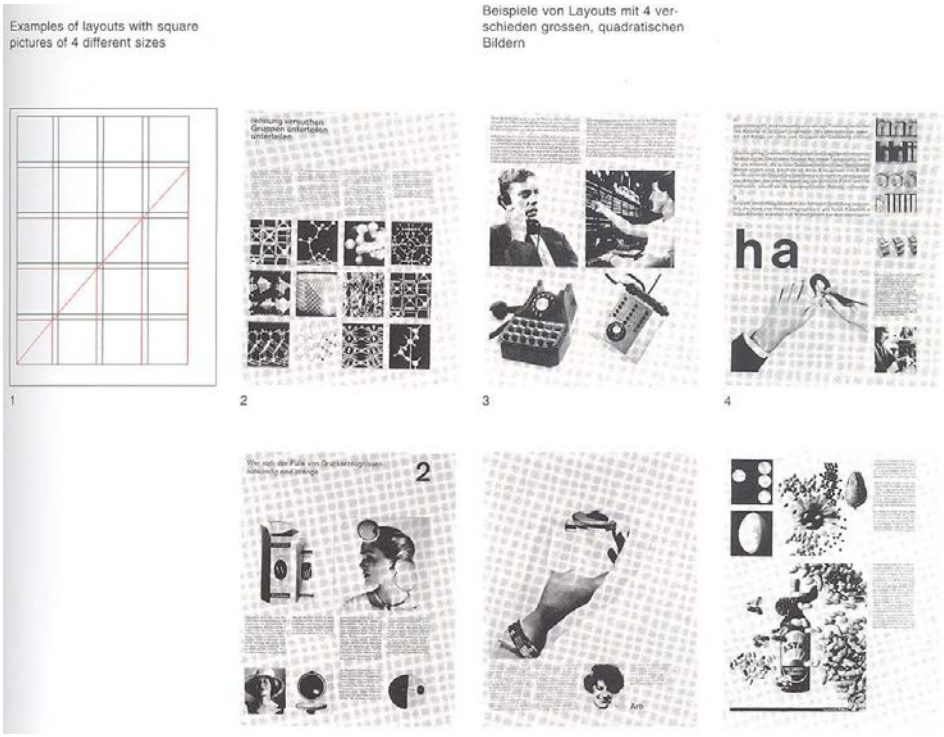

Figure 37. The variations of 4-column grid by Josef Müller-Brockmann, 1972. (http://devkick.com/blog/design-inspiration-european-graphic-design-from-1950-1970/)

4.3.1.4 Science of transparent typography

Outside of Germany and Switzerland, graphic designers also endeavored to find the optimal state of typography. An American-born typographer Beatrice Warde, who did not consider herself as a strict functionalist-modernist, nevertheless suggested an ideal way of typography and printing using the metaphor of a crystal goblet. Comparing wine in a crystal goblet to typographic design, she suggested *transparent typography*. As one should feel the sensation of drinking out of a vessel through the colorless glass, printing materials should convey thought, ideas and images through invisible types. This transparency of typography adds a subtle dimension to the modernists' scientific legibility and readability. "Transparently designed book" implies that readers do not have any visual stimulation while reading the contents, resulting in the inability to recall the look of paper. To Warde, the value of typography is not showing off the quality of structure and layout, but hiding the existence of the containers and fusing the contents modestly (Warde, 1955).

One may consider that the look of graphic design mainly depends on the individual designer's intuition. However, some modern typographers who espoused logical functionality in a micro sense, such as the variation of typographic styles, attempted to find evidences that were empirically proven, or at least compatible between the scientific research and the accumulated experience of graphic designers. For example, Müller-Brockmann mentioned the science of the effective and strictly logical layout: "Information presented with clear and logically set out titles, subtitles, texts, illustrations and captions will not only be read more quickly and easily but the information will also

be better understood and retained in the memory. This is a scientifically proved fact and the designer should bear it constantly in mind." (Müller-Brockmann, 2001, p.13)

Regarding legibility, British typographer and graphic designer Ruari McLean (1980) stressed the three rules: Sans-serif style is intrinsically less legible than seriffed type; well-designed, Roman upper-and lower-case type is easier to read than any of its variants, (e.g., italic, bold, caps. expanded, or condensed versions); words should be set close to each other (about as far apart the width of the letter 'i'); and there should be more space between the lines than between the words. He clarifies that numerous "conditioned" psychological and physiological research has been conducted in order to seek the optimal legibility. However he was not fully confident about the advantage of this scientific research, since designers have known the rules of effective design through centuries of experience. Moreover, he leaves some space for flexibility in that these scientific results may not apply to all cases of typographic design in real situations.

4.3.2. Rationalism grounding the connection

Early data graphics that are composed of primitive graphical elements such as points and lines, as well as simple geometric shapes such as rectangles and circles possess a similar visual aura with modern graphic design's simple, geometric, and functional style. Moreover, contemporary data display in familiar visual conventions dovetails into the 20th century modernism that featured a minimal use of decoration and perceptual principles such as gestalt (Kostelnick, 2008). Thus I argue that the modernists' approaches in graphical forms can be the language of exploring the aesthetics of data visualization. *The modernistic aesthetics provides not only the cues for the surface resemblance that even might seem accidental, but also the rationale for the logical*

attitude to derive the final visual forms. Certainly the designers who were active in the Bauhaus and Swiss Design era were not involved in digital technology with interactivity. Nevertheless their approaches do not diminish in designing reasonable interaction based on rationalism, resulting in aesthetic experiences. The modernist graphic designers' approach operates at a conceptual level, thus it is a sustainable guide.

Prior to linking the formal resemblance, I introduce a simple but sensible view that underlies the legacy of modernist design to digital media design. While arguing that the philosophy and visual language of typographer Emil Ruder has great influence on the current screen design, Kenna (2011) summarizes the principles of modern graphic design as follows:

- A striving for objective presentation through the elimination of decorative and expressive effects
- An unadorned typography that clearly conveys the message to be communicated
- The use of a grid for ordering the information and graphic elements
- The restriction of type sizes and typefaces (san serif, because it was an "expression of our age")

The congested information driven by digital technology needs clarification and navigation. Thus, she argues that these modernist design principles can offer a simple solution that looks fresh and unexpected in the visually chaotic environment of today. Based on this idea, I focus on data visualization as a specific genre of digital media and discuss its link to modern graphic design.

First of all, modern graphic design and data visualization share the most principal goal: effective communication with minimal and appropriate use of graphical elements. By effective communication, I mean both endeavor fluent and logical presentation of information that can be interpreted without much cultural biases (in reality this is not always achieved—it is why I have discussed the rhetoric of visualization in the entire chapter previously).

The modernist aesthetics, which implies geometric layout, orderly typography, and simple color composition, fosters universal forms and aims to objectify representations of cultural diversity by making them appear economical and perceptually transparent (Kostelnick, 2004). Edward Tufte, who is acclaimed as the modern day standards-bearer of data graphics by both visualization scientists and graphic designers (Fry, 2004), also stressed this praise of "transparent" design.

Tufte exhibits many examples of infograhics prior to the era of modernism in his three popular books (Tufte, 1990; Tufte, 1997; Tufte, 2001). Although his chosen examples are not dated to modern era, he finds and strengthens the principles of infographics that are legitimate modernists' disciplines. He profoundly advocates the functionalism of data graphics: "Data graphics should draw the viewer's attention to the sense and substance of the data, not to something else. The data graphical form should present the quantitative contents. … essentially statistical graphics are instruments to help people reason about quantitative information" (Tufte, 2001, p. 91). His notion of visual styles rigidly follows minimalism and anti-ornamentation for clear and elegant display, which is well portrayed in his famous word, *chartjunk*: "Most chartjunk does not involve artistic considerations. It is simply conventional graphical paraphernalia routinely added

to every display that passes by: over-busy lines and excess ticks, redundant representations of the simplest data, the debris of computer plotting, and many of the devices generating design variation" (Tufte, 2001, p. 107) In sum, Tufte's arguments make it possible to switch the attention to the history and principles of modern graphic design in searching for the aesthetics of visualization.

Modern graphic designers' endeavors to find empirical proof supporting their ascetic and functional design principles are compatible with the cognition-based approach of InfoVis scientists. These scientists consider visualization as cognitive tools in problem solving, so they focus on perception, visual attention, and optical problems. Likewise, maximizing the effectiveness of contents delivery was the dream of modernists who championed functional and universal visual language.

4.3.3. Examples of remediation

Previously I explored the connection between early data graphics and the modern graphic design, determining that both had aims of effective visualization communication with minimal and orderly use of graphical elements. Now I attempt to link modern graphic design to the later phenomenon—contemporary data visualization beyond the intuitive and visceral response to their resemblance. My main argument is that, despite the new technologies available to process data and generate the visual object, the modernists' aesthetics is still successful.

The formal resemblance between old media and new media is not the unique phenomena that only takes place in the correlation of the modernist's printed media and computational data visualization. The remnants of old media technology in digital technologies are also extensively discussed by the theory of *remediation* by Bolter and

Grusin (1999). As one defining characteristic of new digital media, remediation addresses the double imperatives of media, *immediacy* and *hypermediacy*; the logic of immediacy explains the status that the medium itself disappears and exists in the presence of the thing represented, whereas hypermediacy recalls the old media forms. These seemingly contradictory logics are mutually dependent. Bolter and Grusin particularly analyze the remediation of visual technologies—how new visual media such as computer graphics and websites present themselves as "refashioned and improved versions of other media" in ways that "honor, rival, and revise" of old media such as photography, film television, and print (p. 15).

Here I exemplify how the visual forms of old printed media are remediated in computational visualization. As presented earlier, dividing two-dimensional space with horizontal and vertical lines is one typical style of De Stijl and later Swiss Design posters and layout systems. The divided spaces are filled with text and often crossed with multiple columns and rows, resulting in multiple rectangles various in sizes. This layout formula is appropriated for Treemap visualizations (Johnson & Shneiderman, 1991) (Figure 38) and the presentation of photos on image sharing or search websites (Figure 39). This is one example of remediation of modernists' space treatment into contemporary web design.

Figure 38. Newsmap (http://www.newsmap.jp)

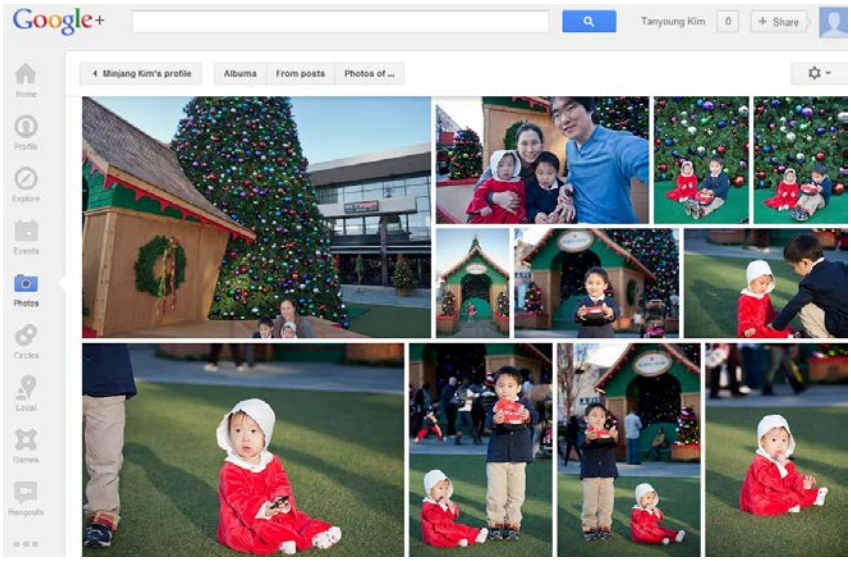

Figure 39. Photo-sharing at Google+

Another example is that the similar visual look between modern typography experiments, which later indirectly influenced Bauhaus and Swiss Style, and Tag Clouds. Viégas and Wattenberg (2008), the designers of Tag Clouds, explained that its looks dated back 90 years to Russian Constructivism. It is not difficult to find that the appearance of Futurists' typography experiments (Figure 40) and that of contemporary

text visualization (Figure 41) are similar. Swiss Design also practiced a more radical typography experiments later in the 1970s, which breaks the rigid obligations of typography.

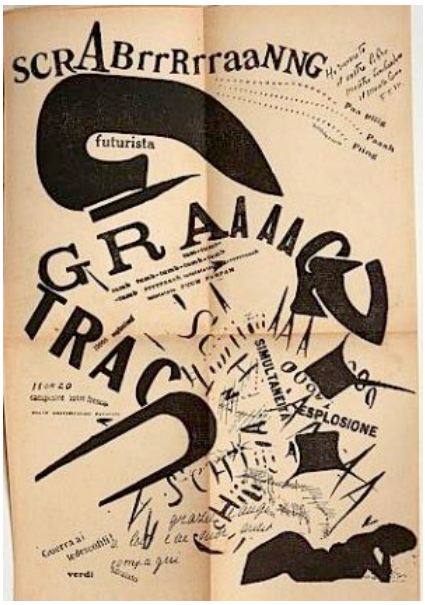

Figure 40. Filippo Marinetti, Mots en Lliberte, 1919. (http://www.artnet.com)

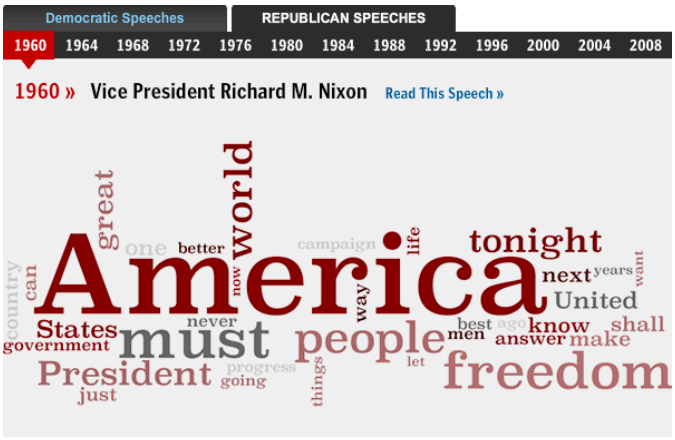

Figure 41. Visualization of presidential candidates' acceptance speech (http://www.washingtonpost.com/wp-srv/politics/interactives/convention-speeches/index.html)

Figure 42.Wolfgang Weingart's typography experiment exhibited in 1969 (Weingart, 2000, p. 279)

The next example is an infographic depicting the number of soldiers killed in the Iraq and Afghanistan wars, posted on *The New York Times* website (Figure 43). The entire infographic is composed of a map, bar graph, and numerous human figures. The vivid colors and the shape of human figures differentiate the nationality and the duty of the dead soldiers. It is an almost intuitive response to find the similarity between this set of universal icons with Otto Neurath's Isotype graphics.

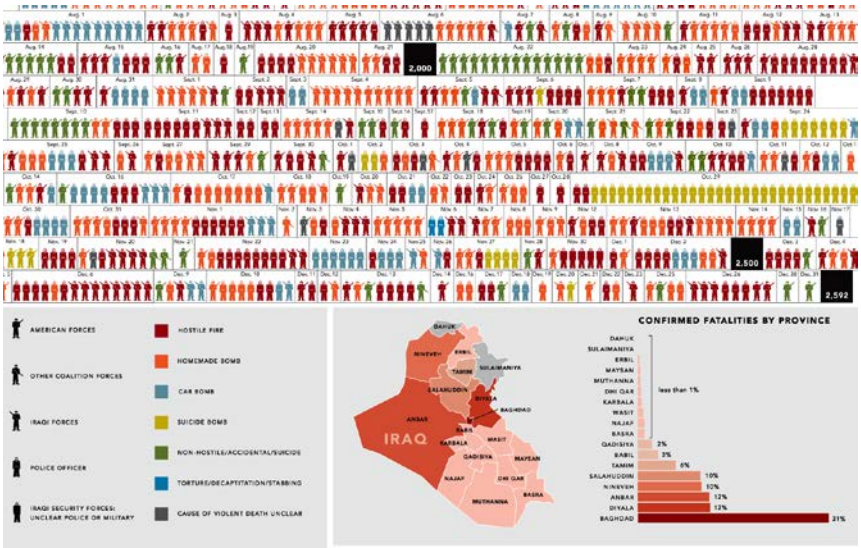

Figure 43. The New York Times, A Year in Iraq and Afghanistan, 2010.
(http://graphics8.nytimes.com/images/2008/01/06/opinion/06opchart.large.gif?sid13)

This section provided the historical lens to seek the aesthetic foundations of contemporary data visualization. Earlier I identified that the aesthetics of data visualization concerns not only the visual appeal from the surface, but also the satisfaction in regards with the use of the system. In this sense, the modernists' approach to seek the visually effective and pleasing visual languages triumphs the rationalism to minimize the subjective intervention. I admit that this idealistic modernists' approach might run counter to the third definition of aesthetics—situated aesthetics. Yet, I argue that modernists' endeavor to achieve the economical and objective forms for both effective communication and visual expression is an appropriate ground of remediation. In the next section, I discuss the influence of computation on aesthetics, which will also cover the situations with aesthetics concerning cultural references.

4.4. Influence of computation on the aesthetics of visualization

Swiss graphic designer Weingart looks back to the early seventies and tells how his focus of aesthetics was influenced by the change of technology. He explains how the advance of printing technology offered a new aesthetic realm in that the lithographic process with its film screen enabled a tonal range of images resulting in a variety of patterns, textures, and gradations.

> The early seventies marker the rapid decline of the centuries-old procedure of handsetting type and letterpress printing; it was no longer commercially variable. My aesthetic interest in the process also evaporated as I become more involved with lithography and photomechanics. Within several years important type foundries and hot-metal typesetters either went bankrupt or converted to phototypesetting, making it difficult for the letterpress printers who were still in business to replace broken lead characters (Weingart, 2000, p. 135).

Weingart's experience tells us that the newly invented technology opened new processes of media production and hence previously impossible ways of representation. Here I argue how digital technology, specifically computation, has influences on the aesthetics of data visualization. It is important to discuss the influence of computing technology on the practices of data graphics, although I maintain the position that modern graphic design is the aesthetic ancestor of contemporary information visualization.

For the discussion, I use two examples of visualization projects that are not a singular image, but a web-based system. *We Feel Fine* is a website that crawls "emotional data," provides six different views of representation of those data, and allows users to interact and analyze them (Figure 44). *ManyEyes* is a public website where users can upload data and create visualizations (Figure 45). By investigating the details of these two systems, I explore how the contemporary visualization evolved thanks to the advent of digital media, as they have influenced many aspects of the cultural contents embodied as text and image—from production to transformation, and to exhibition and distribution. While discussing the characteristics driven by digital technologies along the process of visualization, I relate them to the three aspects of aesthetics that I discussed earlier and the general principles of digital media and environment. At last, I include one rather artistic approach in data visualization—direct visualization—with a visualization artwork, Jason Salavon's *Every Playboy Centerfold, The Decade* (Figure 46). I choose these three examples because they can cover diverse purposes and types of visualization, respectively standing for a user-generated visualization tool, social data visualization, and visualization artwork. By examining the details of these three systems, we explore how visualization can have unique aesthetic qualities as it deals with the cultural contents

represented in images and interactivity. I illustrate how data serve as the backbone of aesthetics, and how the forms and interactions satisfy the project's functionality and trustworthiness, and how the social aspects of visualization are situated.

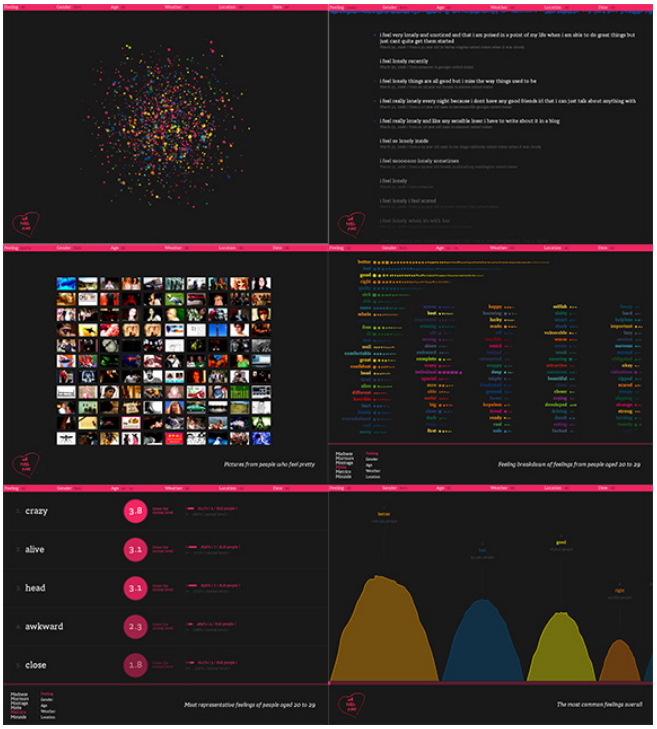

Figure 44. The various views of *We Feel Fine* (Madness, Murmurs, Montage, Mobs, Matrics, Mound) (http://www.wefeelfine.org/movements.html)

Figure 45. *ManyEyes* (http://www-958.ibm.com/software/data/cognos/manyeyes/)

4.4.1. Encyclopedic cultural contents

Unlike other machine learning and data mining research seeking for the optimal algorithms of extraction and classification for sentiment documents, *We Feel Fine* focuses on "building an interface that provides an engaging means of qualitative exploration of emotional data, and a flexible data collection and serving architecture that enables an ecosystem of data analysis applications" (Kamvar & Harris, 2011).

Writing about emotions and taking pictures of eventful moments are cultural activities, which are now happening and observed on blogs and social network services. These *cultural contents* that people leave online are acquired and digitally transformed into the purposeful data collection for this website. The data collection engine of *We Feel Fine* engine *automatically* scours the Internet every ten minutes and harvests human feelings from multiple resources of blogs; it scans blog posts that include the a phrase "I feel" or "I am feeling." Through this process, the system identifies and saves between 15,000 and 20,000 feelings per day. This extensive and growing data collection foregrounds the environment of *encyclopedic* data. Such emotional data include not only the sentence itself as text but also the accompanying images, the date and time of the post, the gender, birthday, location of the author, and the weather of the location and day. This set of emotional data is *numerically* encoded into a *module* and later indexed, searched, and represented later in various forms with diverse interactions.

The material itself in this project highly reflects culture. For example, a woman postings her self-shot semi-nude photo for the feeling "desired" might not be common in some countries where women's social status is low. Furthermore, the way people

communicate with the represented forms also will be affected by their own culture; the interpretation of the visualization would be situated as well.

In *ManyEyes*, users can upload their data sources, which are mostly from open databases on the Internet. Those data are not generated automatically on site but manually collected by the users' volunteering. This participation enables the creation of an *encyclopedic cultural data pool* since the data reflect the current social issues that the users want to visually present and analysis (Viégas et al., 2009). Also these data sets are available for the principal task on the site, that of creating visualizations.

4.4.2. Remediated variable forms for modular data

In *We Feel Fine*, the massive data are represented into six *varied* views (Madness, Murmurs, Montage, Mobs, Matrics, Mound), each of which constructs distinguished interfaces to the same data.

In the Madness view, a primitive dataset as one module is represented in a small circle or square (when a photo was posted together) and moving around. The implementation of this kind of physical movement on screen is what early engineers typically implemented to demonstrate their computational ability for artistic expressions. Such animated images are seemingly meaningless but visually intriguing, and ultimately communicate with users.

As the title implies, the Montage view represents the data modules—including photos—in the grids. When a user selects one of these photos in the macro view, the view is switched to a micro view of the selected photo. In the micro view, the photography is enlarged to fill the entire screen and overlaid with text showing the other dimensions of the data module. The visual look of the macro view—where the collage of pictures is

displayed—can bring the impression of the *remediation* of magazines (where the collage of pictures is displayed) whereas the micro view adopts the images of television.

While maintaining their own forms (the remediation of early computer graphic art, magazine, and television), some of the views share several visual elements such as colors. For example, they all use the same color-coding assigned to each of around 5,000 pre-identified words for feelings.

4.4.3. Aesthetics of pre-designed forms

Since its launch in 2007, *ManyEyes* has received much attention from both non-academic Internet users and visualization researchers for its novel mechanism for end-user creation of visualizations. In regards to the aesthetics of computational visualization, here I focus on the two features of *ManyEyes*: its variability of visualization forms with limited choices of aesthetic expressions, and the role of medium that spurs discussions around such visualization builders.

The most advanced technology of *ManyEyes*, when it was first introduced, was that it realized a need for the creation and publication of interactive visualization at the level of non-programmers and non-specialists in contrast to frameworks such as Flash and Processing or other user tools such as Tableau. Using the World Wide Web as a platform of creating visualization is nearly the only requirement, since users do not need to install any software except a Java-based applet to run the visualizations on their web browsers. From the perspective of information architecture, the *ManyEyes* website strictly follows the typical structure of traditional websites: three main menus (Explore, Participate, Learn More), and the sub menus under each main one. Also the main page of the site exhibits several user-generated visualizations. I argue that this familiar

environment lets the users not feel overwhelmed or obligated to “learn” something new and difficult.

More importantly, the website kindly instructs in a simple manner: 1) Choose a data set, 2) Choose a visualization, 3) Customize and publish. After selecting a data set among those that are already uploaded by other users or uploading his or her data set, a user selects the type of the visualization. The visualization selection page is straightforward and informative. According to the types of the data and the purpose of the data analysis, users can choose among one dozen graph types for tabular data, four types of text visualization, and world, country, and several U.S. state maps. This process is not much different from the task of making charts on Microsoft Excel. Depending on data schema (axis, numerical or textual formats), multiple visualization forms are available to code the data. On each visualization type, users can perform “contextual data transformation” or reshaping. Although users cannot change the data itself, they can manipulate or filter the data in the context of creating a visualization. For example, users can flip row and columns.

This visualization creation method is one example of the digital media environment perfectly explained by Murray’s characteristics—procedural (first data upload or selection, then visualization creation), participatory (users’ active involvement in generating contents of the website), and encyclopedic (ultimate collection of the users’ data sets and visualizations). Also, the various possibilities of the data manipulation and visualization are based on the numerical coding (text data transcoded for Wordle style, for example) and variability (different available visualization types of a same data set).

These theories explain the phenomena of "expansion" by digital technologies compared with analogue era. They focus on the qualities of the quantitatively enlarged situations such as variable forms, automated and fast production, and easily accessible manipulation. However, one unique and important characteristic of *ManyEyes* is not analyzed from such perspectives: the *pre-designed, thus inevitably limited as expressive forms*. In fact, it is opposite to the concept of a participatory, interactive, and encyclopedic digital environment.

ManyEyes does not allow users to manipulate the selected visualization type at the level of changing sub-visual elements. For example, the circular form in Bubble Chart is the most intuitive way to compare the numbers; but one may want to use a star shape if he or she considers the shape fit for the theme of the visualization. In addition to this limited choice of the visual forms, users do not have a full freedom to choose other primitive graphical argumentation such as colors and fonts.

This template-based system clearly cannot offer chances for infinite expressions. There are several advantages of such pre-defined and customizable forms with limits, which lead to aesthetic achievements. First of all, this procedural customization guides users to the task completion without a significant failure. This aspect supports functionality of a system. Second, we may have a tacit belief that the given set of colors and fonts has been meticulously selected to pursue the maximum effects of visual communication on the platform. This granted awareness can have positive effects on aesthetics as the credible utility. Last, the general visual style of *ManyEyes* is distinctive and somewhat recognized. Thus when people encounter images generated by *ManyEyes*, they might give higher credibility to them than other random chart images.

4.4.4. Interaction bridging functionality and storytelling

Designers may append interactive cues onto the surface of the visual forms to afford navigation. Navigating the data-based interface does not only support the visual analysis of the contents but also surfaces opportunities for rhetorical interpretation in the visualization as an aesthetic sphere. Through exploring the different interactive features, users can discover insights and generate stories that were either intentionally devised by designers to be found or dependent on the users' self-exploration and interpretation (Hullman & Diakopoulos, 2011).

Three last views that appropriate typical visualization techniques (Mobs, Metrics, Mounds) have interactive features that are straightforward and functional, providing the following functions: select, explore, reconfigure, encode, abstract/elaborate, filter, and connect (Yi et al., 2007). These visualizations of the encyclopedic data serve as an interface to switch between macro-level (summarization of all given data) and micro-level (browsing an individual atom), as well as to analyze and navigate the diverse dimensions of the data.

The interaction triggers in other views (Madness, Murmurs, Montage) also support these technical actions, but they do not appear "cold" in the same way other task-oriented systems might. They use the Web environment as an art space, and harness the technology of this platform to materialize the many narrative experiences. In other words, the designers consider this visualization system as a means of storytelling that re-imagines human emotions; they erase the pure functionality of the interactive features of the visualization by merging them into the playful navigation of an experimental data visualization.

As previously discussed, the Madness view resembles generic computer graphics that simply demonstrates computing power, but now the computational forms are adopted to encode emotional data. Each particle represents a single module. Since the particles are numorous, and the users do not intuitively understand the use of diverse colors, the entire moving image might not look insightful at first. As the designers of *We Feel Fine* describe it, the relationship between the user and this view is like as a person standing atop a skyscraper and looking down at people down on the street (Kamvar & Harris, n.d.). The observer can neither hear their talk nor see their facial expressions. However, when a user clicks a particle, it explodes into its constituent letters, which procedurally form its sentence. The full sentence is displayed, and now the clicked particle becomes the center of attention. The change of particles triggered by mouse interaction is amusing and even poetic as this view simultaneously follows strictly the typical interaction rule of visualization, “details on demand” (Shneiderman, 1966).

4.4.5. Platform for secondary data exploitation

One technological advance beyond the experiences with the presented data and visualizations is the fact that *We Feel Fine* provides APIs. Many data-rich Social Network Services such as Twitter, media archive sites such as Flickr, and online journalism sites such as *The New York Times* offer APIs and let the third-party individuals and institutions utilize the open data, which creates another sphere for other numerous applications. Since the currently provided APIs are not stable, I am not able to find any working interactive applications, but there exist several static images that use API. However, the advocacy of this API reflects the openness of web ecology: “Since we are borrowing from the feelings of thousands of people across the world to make our

piece, we find it fitting for other artists to be able to borrow from our work to make theirs." Ideally the data accessed through the APIs would be further data analysis by social scientists or be reborn as other pieces of artwork.

4.4.6. Direct visualization for cultural visual media

In the traditional sense of visualization, the range of data is limited to discrete or numerical forms that should be reduced to some degree in order to create an image beyond a spreadsheet filled with rows and columns of numbers. However, Manovich expands the sphere to include visualizations that are not reduced, which he calls *direct visualization* or *media visualization*. Media visualization creates "new visual representations from the actual visual media objects or their parts. Rather than representing text, images, video or other media through new visual signs such as points or rectangles, media visualizations build new representations out of the original media. Images remain images; text remains text." In direct visualization, a non-reductive visualization, the data is reorganized into a new visual medium that preserves their original form. For example, in a "tag cloud," the text itself is represented without being reduced into bar graphs or pie charts; instead, the size of the text is varied to illustrate frequency of the word.

More creative forms as direct visualization have come to life thanks to the advances of image processing. One media-claimed artist is Jason Salavon whose works can be labeled as direct or media visualization that Manovich named. One example is a series that analyze *Playboy* magazine centerfolds from January 1960 to December 1999 (Salavon, 2002). Each piece is produced through averaging all the foldout images of a

decade (Figure 46). The look of the results of the image processing is original and arresting.

As we look at the Salavon's piece, we obviously detect the change of colors of nude body and hair in a blurred and surrealist-like painting form. Bodies become thinner and lighter in skin tone as the years progress. Beyond the visual perception, this observation provokes *situated and social questions* relating to our own visual culture and gender issues. For example, one might ask these questions: How is the change of male gaze toward women depicted in the mainstream adult industry media? What are the demographic and consequent cultural changes that affect the "average taste" of heterosexual males over time? Does this change reflect men's shared idea of a sexy woman, and how is it different from the women themselves' ideal body image? We can also imagine that, at even an early phase of visualization production, the artist may have deliberately selected these visual media data because they can best answer those questions above for rhetorical purposes.

Every Playboy Centerfold, The Decades exploits an existing image processing technology for artistic expression, but what we emphasize here is not the mere creative process concerned with the finished artifact. What makes this visualization art a critical practice is its approach to "sizing up and reformulating a terrain of knowledge as well as experimenting with new and alternative forms" (Hall, 2008). The artist frames a social and gender issue as a subject of visualization, then utilizes a major adult magazine whose contents are substantially affected by the culture of the time. This visualization summarizes the forty-year archives of printed media into four images to construct situated and cultural knowledge on the viewer's side.

In this chapter, in parallel with the previous chapter on rhetoric, I have discussed the aesthetics of data visualization with a focus on the new affordances by computation. Aesthetics is not well defined in the fields that conduct visualization research and practice. Starting with acknowledging this problem, I answer the second part of the research question regarding aesthetics of visualization. I first reviewed how aesthetics had been discussed and interpreted in the related fields, and defined the new aesthetics of data visualization. Then I argued for the historical ties of remediation between modern graphic design and data visualization. Based on the new definitions and the vocabularies from digital media studies, I articulated the new aesthetics of data visualization allowed by computation. Ultimately, the work from chapter 3 and 4 completes the first research question: What are the influences of computation on visualization? To be specific, how does computation affect the *rhetoric* (chapter 3) and the *aesthetics* (chapter 4) of visualization? In the following chapter, I attempt to integrate these two theories and synthesize a novel idea of data visualization, which is summarized in a new term: coded visualization.

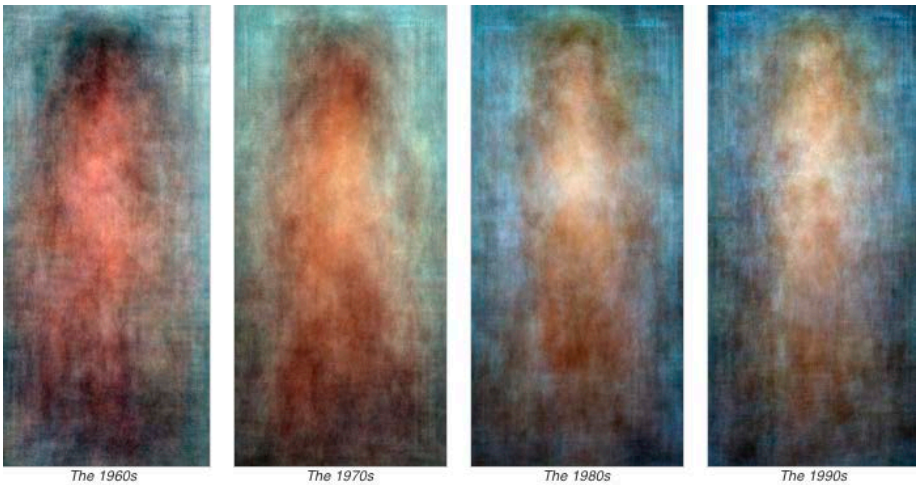

Figure 46. Jason Salavon. *Every Playboy Centerfold, The Decades (normalized)*. 2002. Digital C-pints. Ed. 5+2 Aps. 60” x 29.5” (http://salavon.com/work/EveryPlayboyCenterfoldDecades/)

Chapter 5

Characterizing coded visualization

In this chapter, I attempt to connect rhetoric and aesthetics of data visualization and argue that they are not separate entities but a cohesive concept for digital media studies. To clarify these characteristics of data visualization, I coin a term "coded visualization," which covers the neglected aspects of data visualization in the previous research, and links rhetoric and aesthetics as a unified theme.

First, I define the terms "coded" and "code." They have an expanded meaning of mainly technical term "computational" or "computation" and, more importantly, suitable for bringing the aesthetic and rhetorical aspects of data visualization together. Then I compare and contrast coded visualization with the previous definitions and purposes of visualization from computer science and digital humanities. As an additional way to identify coded visualization, I summarize the roles of coded visualization as *cultural interface*. Cultural interface is a crucial term to explain visualization as a work of digital media design. Finally, I suggest design criteria of data visualization that embody the characteristics of coded visualization.

5.1. What code means in visualization

Visualization is a mapping of computer-supported mapping of data to visual forms. The term "code" originally contains dual lexical meanings—1) code as information representation or abstraction as in computer science, 2) code as sign in semiotics. Considering the fundamental condition of visualization and the two original

meanings of code, I now provisionally define coded visualization as *a visual media whose core imagery is the computational representation of data and through which the messages are coded and decoded*. Starting with this basic definition of coded visualization, I first articulate what "coded" means in visualization, the expanded concept of "computational." The advanced discussion on code is following; the two meanings can imply aesthetics and rhetoric respectively, and the term "coded visualization" ultimately implies that aesthetics and rhetoric are united and influence each other.

5.1.1. From computation to code

Visualization is a formal logic, but situated, subjective and partial forms of knowledge production. In other words, *visualization is a computational artifact where aesthetic, rhetorical and interpretative events occur*, and this is the summarized statement of what I discuss in the previous two chapters: rhetoric and aesthetics of visualization. What I mean by "computational" in the last sentence is more than simply computer-supported or made-with-computer. Below I present how the term, "computation" has been used in a confined manner, contrast it to what I mean it in this thesis, and explain why I use "coded" rather than "computational" for the computer-generated visualizations.

5.1.1.1 Code as the quality of digital process

In this thesis "Computational Information Design," Fry (2003) uses the term "computational" in such traditional and technical sense. He sees that the problematic aspects of the contemporary information design are the vastness and complexity of inquired data and the methods of interaction with the data. In short, the thesis is about dealing with these problems through computation. Fry summarizes what he meant by

computation—computation is a means for handling the repetitive aspects of representation (since machines are best suited for such repetitive acts). Thanks to the computing advances, the consolidations among the stages of visualization process have occurred similar to the desktop publishing technology that has made the procedural job of layout, typesetting, and printing seamless. Moreover, the process from acquiring data to refining visual representation, and to adding interaction has become more flexible and efficient. However, computation itself, especially Artificial Intelligence research, is not good at deciphering the meaning of what is produced through computational process. Thus, finding insights from the results of computation is the job of humans; computation only supports decision-making, analysis and prediction (p.120).

The principle of computation by Fry matches to the meaning of *code* as an activity of programing and the mapping from one to another. In computer science and electrical engineering, code refers to a rule for converting a piece of information into another form of representation, not necessarily of the same type. In addition to the lexical meaning, in spoken English “coding” or “writing code” refers to the activity of creating a series of textual operations using computer programming languages. Thus, the past-tense verb form “coded” meets the essentials of visualization: an artifact is created through computational process, the course of programming language. Therefore, the term code stresses that computational visualization possess special properties that are not be realized with analogue production skills.

5.1.1.2 Code as symbolic messages

In contrast to Fry, who defins computation as automated process for processing repetitive tasks, art and culture critic, Johanna Drucker (2009) expands this meaning of

computation and encompasses symbolic realm in explaining the principles of computation. Fry's computation is refined in what Drucker means by *calculation*. Calculation is a certain function that can be automated through mechanical or digital means, but it only treats quantitative values, numerical information; computation makes use of signs that represent any information. Through computation, extra symbolic values are coded onto the binary entities or formal logic.

Drucker's idea of computation infers the semiotic and rhetorical possibilities of computer-generated images. This phenomenon is explained under the term of "code" in semiotics. A French theorist, Roland Barthes (1978) introduces the languages of semiotics to formulate how images we see everyday work to create meanings in the contrasting two ways. *Noncoded iconic message* is the literal translation of what is it in the image, whereas *coded iconic message* is the totality of all of the messages connoted by the image itself. Visualization is often understood as a noncoded iconic message because it is a transparent and scientific representation of objective data in its own defintion. However, as I discused earlier, there exist chances of noise throughout the creation of the visualization process. The noise brings the subjective and situated interpretation of *coded* visualization.

To summarize, according to Fry and Drucker, the term computation means both—1) the formal logic that composes the protocols of representation through automation and quantitative process, and 2) symbolic values that are coded additionally to the electronically processed entities. Although these meanings match to the dual meanings of code, I decide to use "coded" instead of "computational" to characterize the new focus on visualization research of this thesis. Beyond the technical term of computation, "coded"

brings immediate association of the both digitally mapped entities and encoded symbols to be decoded later. In addition, I hope to simply distinguish the focus of this dissertation—rhetoric and aesthetics—from what has been discussed under the terms, computational visualization or computational information design.

5.1.2. Linking aesthetics and rhetoric

The more important reason that I use "coded visualization" as a core of this thesis is that it can integrate aesthetics and rhetoric of visualization. Aesthetics and rhetoric of visualization are not disparate but influential to each other. The transmission mode—encoded, stored, output—is not unambiguous but undergoes critical interpretation. The formal aesthetics affects the communication, and the requirements for communicative needs limit or open opportunities for unique aesthetics.

Drucker indicates that the graphical form of information itself is information and creates a new rhetorical force of digital media. In other words, the new environment of digital media, namely "interface" to the information, functions as novel rhetorical devices that are distinctive from traditional visual media.

> The cultural authority of computing is in part enabled by that neutrality. Likewise, the graphical forms through which information is displayed online are shot through with ideological implications. The grids and frames, menu bars and metaphors of desktops and windows, not to mention the speed of clicking and rules that govern display, are all ripe for a new rhetoric of screen analysis. The graphic form of information, especially in digital environments, often is the information: design is functionality. Information architecture and information design are not isomorphic. Therein lies another whole domain of inquiry into the rhetorical force of digital media (Drucker, 2009. p.17).

Drucker's view on the rhetoric of digital media is also opposed to the notion of transparent or invisible interface. By hypermediating the interface, which implies that the users experiencing the interaction with the media, digital media exert rhetorical powers. In this sense, the rhetoric and aesthetics are not disperate abstract concepts, but perceived in a unified and holistic experiences around digital media.

In fact, I discussed this idea briefly earlier while I suggested that one angle to look into the aesthetics of visualization was "situated aesthetics." To revisit a core concept of speculative computing, visualization is not a mere device for the objective and direct reading of formal languages without cultural interventions, but a space where aesthetic, cultural, situated, and rhetorical interpretations, and further new types of knowledge can be realized. In other words, these perspectives on visualization (asthesis) counterbalance the perspectives on visualization as sciences for cognition and perception (mathesis). What is insightful to me about the approaches of speculative computing is the fact that they do not clearly divide formal properties and rhetorical influence of visualization.

Earlier this section, I addressed that coded visualization was "a visual media whose core imagery is the computational representation of data and through which the messages are coded and decoded." As a conclusion of my arguments of "code" in visualization, I add a crucial quality to the previous definition. *Coded visualization is a data-based interface whose visual form is an aesthetic space where messages are coded through computational process and interpreted with cultural references.*

5.2. Differences form previous concepts of visualization

Based on the definition of coded visualization, I illustrate how it is compared and contrast with currently known knowledge about and use of visualization in computer

science and digital humanities. In my own definition, coded visualization is an interface that can be appreciated in diverse manners according to viewers' situational and cultural circumstances. Thus, I identify coded visualization as a cultural interface at the end.

5.2.1. Rhetorical use of aesthetic visualization

One of the most well-known definition of visualization is from Card, Mackinlay, and Shneiderman—the use of computer-supported, interactive, visual representation of data to amplify cognition (Card et al., 1999, p.7). This definition highlights the purpose of visualization; cognition means "the acquisition or use of knowledge," so visualization is made for gaining insights that lead to discovery, decision making, and explanation. Another clarification in defining visualization is the use of computer, so the visualization is not static but interactive. Strictly following this definition, early data charts by scientists and currently abundant "long infographics (Feltron, 2010)" static images by graphic designers may not be in the safe zone of visualization.

The goal of visualization, to amplify cognition, is repeated in other literature in science. Focusing on the science of human perception, Ware (2004, p. 3) discusses that visualizations have advantages in comprehending huge amounts of data, recognizing unanticipated properties, making unapparent problems in data visible, and facilitating the feature of data from both macro and micro perspectives. He also presents a short notion on the semiotics of visualization—how visualizations are made up of symbols and their meaning are created by conventions of human-to-human communications. However, he maintains the perspectives that "craft or art" of visualization is opposed to the science of it, and visualization as a kind of language is only an alternative view that does not consider visualization as a science.

Same as those definitions by computer scientists, coded visualization is an artifact of computational process and it provides the knowledge of the represented data. Moreover, coded visualization is not a static image that graphic designers used to make without digital technology. Like the highlights by computer scientists, coded visualization is interactive and functions as an interface between data and viewers.

However, coded visualization is distinguished from the scientists' concepts in the scope of aesthetic boundary. The existing definitions of visualization merely focus on its surface—transformation of non-visual data into visual forms. In contrast to them, the adjective "coded" intrudes the surface of visualization and values the aesthetics of visualization as its formal logic, pleasure of interaction, and situated interpretation. Aesthetics is a holistic experience surrounding the visualization, not simply a crafty execution for the pretty surface. Moreover, through the experience, coded visualization aims at providing possibilities of gaining insights beyond the facts found in the data. The insights may vary depending on the viewers' own interpretation of the visual forms and the interaction with them. The wide spectrum of understanding and harvested knowledge through a visualization does not mean that the visualization is not a matter of science but it plays a role of a cultural artifact.

At last, I compare coded visualization with artistic visualization. Visualization researchers Fernanda Viégas and Martin Wattenberg (2007) examine an alternative situation revolving visualization in their article "Artistic Data Visualization: Beyond Visual Analytics." Artists appropriate and repurpose "scientific" techniques to create art pieces that guide viewers' investigative reasoning and contextualized reading of their subject matters. A design critic Peter Hall (2011) also discusses such artistic approach as

he suggests three categories of visualization—scientific, journalistic, and artistic. In Hall's view, artistic practice reflects cultural condition and is the only chance in which visualization can be exempted from the "evaluation solely in terms of usability issues." The work of artistic visualization is critiqued based on the concepts, novelty, and crafty perfection at execution, which are the concerns of aesthetics.

This emphasis drives artistic visualization to the "visualization exploration" side in the model of design research in visualization, which is partially what the practice of this thesis will pursue. The creative expression of artistic visualization is a shared concern with coded visualization. However, coded visualization does not solely aim at finding creative and expressive techniques of data mapping techniques, but allows cultural and rhetorical use even in the forms that might even look like traditional charts at surface.

5.2.2. Beyond an analysis tool in cultural analytics

At the very opposite side of computer science, liberal arts have also shown interests in visualization, specifically in the emerging scholarly field, digital humanities. Emerging in the late 90's, digital humanities grew out of an attempt to use computing methods in understanding textual materials (Fitzpatrick, 2012). Digital humanities have the following basic elements—statistical processing, structured data, metadata, and information structures (Drucker, 2009, p. 9). This analytic process mitigates traditional texts into electronic forms and help to do certain things that are otherwise impossible or difficult with print text. To digital humanists, visualization is a digital tool that provides a different way to interpret literary and other humanities text.

Cultural analytics is a nascent research method in digital humanities (Manovich, 2007). The methodology of my thesis, design research on visualization, is compared with

this. As Hall introduces, “the concept of cultural analytics can be seen as the consequence of ever-increasing computational power to manipulate enormous amounts of data in real time, the ability of advanced visual interfaces to explore these datasets, and the desire of researchers to explore such resources in new ways.” It uses visualization as a critical tool to analyze the patterns of cultural data that are mostly generated on social media such as Twitter, Flickr, and Youtube. The data are both broader and deeper than the ones that previously obtained in social science methods such as survey (shallow but wide) and ethnography (deep but narrow), although the volume is not as “big” as what computer scientists premise (Manovich, 2012). An example is analyzing hundreds or thousands of digitalized paintings and native-digital data such as Youtube videos (Zepel, 2011). In Zepel’s work, the cultural data are already visual media, and they use direct visualization techniques.

Admittedly, my research on coded visualization is much affected by digital humanities, but I do not aim at defining this thesis as a work of solely this field. There are both similar and distinguished aspects in the comparison of coded visualization and cultural analytics. My vision of “visualization through design research” is similar to that of cultural analytics in a sense that the data or resources of data are expanded beyond what used to be the interests of scientists. The data of coded visualization would meet humanists’ curiosity to find patterns in visual media. In addition, utilizing big data to observe the patterns of people who are the generators of the data, and their socio-political context does not much differ from a role of coded visualization.

However, coded visualization as a subject of design research does not constrain the raw materials within visual media or online data from various social media nor

depend on their massive size. Thus how to process computationally or digitize cultural data is not the main focus of design research. Instead, dealing with visualization as the subject of design research, one focus of my thesis is the new aesthetics driven by computational creation, which is not a particular interest of cultural analytics. I also focus on the new rhetorical effects of visualization itself as a medium of representation, while cultural analytics scholars focus on the rhetoric of the data as row contents.

Finally, the purpose of the research should be distinguished. As the term itself implies, in cultural analytics, visualization is mainly used to present the result of analysis, or for some occasions it is used as a tool for visual analytics in which researchers can gain knowledge. In contrast, the entire process of making coded visualization is the interest of research. Moreover, the primary goal of making coded visualization is not to help designers analyze the patterns found the data. Coded visualization is meant to be communicative, argumentative, or even persuasive by representing potentially thought-provoking cultural data to the audience.

5.2.3. Cultural interface

Previous definitions of visualization by computer scientists and others do not explicitly address that visualization is an interface although they assume visualization must be interactive. The most distinguished and the central argument of my thesis is that *a coded visualization is a cultural interface.*

Interface is a broad term used in many different contexts. In computer science, it first means a piece of hardware such as keyboard and printer. Second, it refers to “the almost ethereal dimension containing everything the user sees on the screen, and what is heard from the loudspeaker when the programme is used” (Bonseipe, 1999, pp. 57-58)

The second meaning matches what has pervaded the practical fields of interface or interaction design. In the 1980s, the interface was defined as "a specification of the 'look and feel' of a computer system" in a very narrow sense, and "the totality of all communication between the computer and the user" in a broader sense (as cited in Bonseipe, 1999, pp. 42-43). In such a traditional interpretation of interface, designers' contributions were limited to the visual aspects. Moreover, the functionality-centered view emphasizes the "transparency" of interface, as it considers interface as a tool for seeing.

In contrast to the screen-based and functional roles of interface, the expanded concept of interface requires the linkage of body (user), tool (artifact), and purposeful action (task). Thus, interface is now the central domain on which the designer should focus; the design of interface determines the scope for action by users of tools. Interface reveals the character of objects as tools and the information contained in data (Boneipe, 1999, p. 29). The idea of interface that reflects the contents of artifacts relates to some concerns of coded visualization—aesthetic communication and visualization as a rhetorical device.

Manovich (2001) uses "cultural interface" to explain the ways in which computers are used to produce, store, distribute, and access cultural contents so that people are interfacing not with a computer as a machine, but with culture encoded in digital form. I argue that beyond the technical conception of interfaces (e.g., input/output devices, the desktop metaphor), a cultural interface provides audiences with a space where they engage in the holistic process of making, using, and sharing cultural artifacts. He also discusses that fundamental ideas of human-computer interaction are the new

ways to represent any data, which has to do with “culture” by default. In sum, new media is concerned with cultural objects and paradigms enabled by computing (Manovich, 2003, p. 16).

A coded visualization is a digital form that makes unnoticeable problems visible. In other words, the problems are already incubated in the data and they are encoded in the process of making visualization. There are many occasions of encoding procedurally on a designer’s side, including obtaining a favorable data set, selecting visualization techniques, and embellishing the design with culturally meaningful visual elements. A user as a social agent interacts with multiple types of visualization-based digital media that include the encoded cultural data. While interacting with a visualization, he or she reveals the characteristics of the media and the information from the data and finally uses the media and information for rhetorical purposes.

In this section, I characterized coded visualization from other types of visualization including artistic visualization and cultural analytics. I did not exclusively categorize visualization, but stressed how coded visualization could be a novel concept of visualization. I summarized the highlight as “cultural interface” because visualization had many chances to be culturally charged throughout the design process. In the next section, I focus on these characteristics and suggest design criteria for design practices.

5.3. Coded visualization for research-through-design

So far in this chapter, I have argued why I coin “coded visualization” as a representative term for the significance of this research—it implies the integrated aesthetics and rhetoric of computational visualization as a cultural interface. I also articulated how coded visualization could be distinguished from the previous definitions

and the use of visualization in computer science and digital humanities. Founding on these discussions, now I present design criteria of coded visualization. As an output of design research (knowledge construction), these criteria do not aim at providing immediately applicable technical how-to-dos for the implementation of visualization, but opens a new set of considerations in designing visualization that exert the characteristics of coded visualization as an aesthetic and rhetorical digital medium (research through design). The criteria are aligned with the design dimensions of coded visualization that also match the new rhetoric and aesthetics of computational visualization that I have discussed earlier in chapter three and four.

5.3.1. Process of coded visualization

Many scholars have defined visualization and certainly their definitions reflect the research scope of the discipline they belong to. However these traditional boundaries of discipline-oriented definitions do not always encompass the recent shift or expansion of interests, which is the main concern of coded visualization. To make the design criteria of coded visualization in a different scope from other visualization research, I start with rethinking the process of visualization—from data acquisition to interaction design. Then I expand the previously known processes to suggest a new pipeline of coded visualization.

5.3.1.1 Previously suggested process of visualization

One simple definition of visualization by Card et al., (1999, p. 17) is “adjustable mappings from data to visual form to the human perceiver” or “mapping of data to visual form that supports human interaction in a workspace for visual sense making.” In a schematic model of this concept, a series of data transformation, the flow starts with *raw data* then goes to *data tables*, *visual structures*, and finally to *views* (Figure 47). Raw data

exist in idiosyncratic formats and they are transformed into table, an intermediate step. Data tables now include mathematical and relational description and extended metadata in a form of, for example, spreadsheet with columns and rows, indexed strings or arrays, and document vectors. Through the next step, the data tables are mapped, or encoded to visual structure such as spatial elements and other graphical properties. Finally views refer to the graphical parameters such as positioning and scaling. At each step, there is human intervention indicating that each transformation is adjusted by user-operated control.

Ware (2004) suggests a process of data visualization that includes four basic stages combined in feedback loops, which does not much differ from Card, Mackinlay, and Shneideman's reference model. Ware's four stages consist of the following and I matched it to the previously presented model.

- The collection and storage of data itself: Raw Data
- The preprocessing designed to transform the data into something we can understand: Data Tables
- The display hardware and the graphics algorithms that produce an image on the screen: Visual Structure and Views
- The human perceptual and cognitive system (the perceiver): The agent who does tasks and sends and receives the feedbacks to the other three stages.

What is notable in Ware's process is the inclusion of social environment in data-gathering loop despite his strong focus on the sciences of human perception and cognition. While physical environment is the technical feasibility of obtaining data, social

environments determines the subtle and complex ways in which data are collected and interpreted.

Fry (2004), a pioneer of visualization at the intersection of art and science, also suggests a model of understanding data and creating "Computational Information Design": *acquire, parse, filter, mine, represent, refine, and interact* (Figure 48). In this idealized procedure, reduction of raw data is required at the phase of both obtaining (parsing and mining) data and visualizing (representing and refining) the data. One eminent aspects of Fry's pipeline is that he describes the specialized fields at each step. For example, acquiring and parsing data is a job of computer scientists; representing and refining the data is what graphic design can do. Fry explains the definition and the goal of the individual disciplines that contribute to grounding his focus, Computational Information Design.

Manovich suggests two principles of visualization—reduction and spatial variable. In a traditional sense, visualization is able to and meant to show patterns and structures in the data by employing graphical primitives such as points, straight lines, curves, and simple geometric shapes. This process should accompany extreme schematization and reduction, which privileges spatial dimensions over other visual dimensions. In other words, in order to represent the key differences in data and to reveal the most important relations, spatial variables such as position, size, shape, and the curvature of lines are used. Later less significant properties are represented in non-spatial visual dimensions, such as color or shade. Although Card, Mackinlay and Shneiderman do not prioritize visual properties explicitly, Manovich's idea, mapping to spatial properties, matches to the their visual transformation.

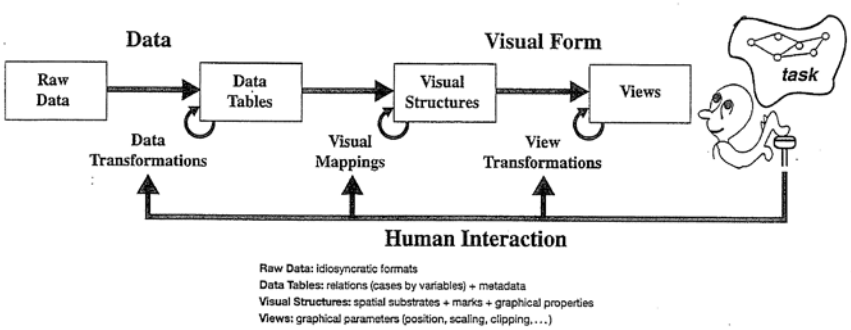

Figure 47. Reference model for visualization. (Card, Mackinlay, and Shneideman, 1999, p. 17)

Figure 48. Fry's process of understanding data (Fry, 2003, p.13)

5.3.1.2 Expanded pipeline of visualization

Here is the summary of the previously proposed processes of visualization:

- Raw data, data tables, visual structures, and views (Card, Mackinlay, and Shneiderman)
- Data collection and storage, data processing to readable entities, producing images with graphic algorithms, and perceiver controlling the stages (Ware)
- Acquire, parse, filter, mine, represent, refine, and interact (Fry)
- Data reduction to spatial properties (Manovich)

This mapping-oriented process well explains visualization as a science of perception and cognition of graphical elements. The feedback loop between these steps and human agent reflects the iterative process of visualization design. The sequential and continual change of questions in data processing emphasizes the specialized role of the involved disciplines. However, I argue that there are missing aspects in these processes of

visualization in the wider context than the confined definition of visualization, visual mapping of raw data.

First, these processes do not specifically address the phase of generating data from scratch: where do the data come from? Who originally makes the data? What are the technological and social limitations and opportunities in generating the data? Second, they deal only with the steps for "making," and do not cover post-making concerns such as when and where to disseminate the interactive visualizations. The processes are solely written from the perspective of makers—not audiences (or viewers, or users). Moreover, in those well-known processes of visualization, there is no apparent distinction among maker and audiences and the environmental concerns around them. In many cases, however, visualizations are made to be exhibited to other people, to be shared later, and even to be appropriated.

Thus, reflecting the larger context of creating data and sharing visualization, I suggest the expanded design spaces of visualization: Resources, Contents, Form, Interactivity, and Platform. These five spaces initially adopt the process of visualization including conceiving data, organizing the data, embodying the visual forms, appending interactions to the forms, and exhibiting and sharing the final output, chronologically. The details of each design space is:

- Resources: conceiving data through various methods, deciding the origins of the data, as well as "what counts"
- Contents: obtaining existing data, structuring and ordering into categories, selecting favorable datasets

- Form: determining the effective representation techniques, employing visual design conventions to move towards the designer's intention
- Interactivity: adding methods of manipulating contents and the form from viewers' side
- Platform: deciding the appropriate environment to present the created visualization to target audiences, providing the viewers with the opportunities to share the visualization and discuss the visual medium and its effects.

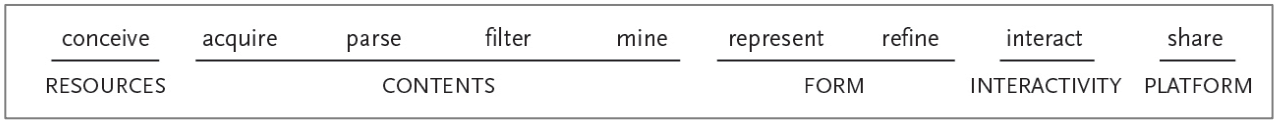

Figure 49. Expanded pipeline of visualization process

5.3.2. Design criteria for coded visualization

Other types of visualization mainly concern the visual mapping of data. This definition of visualization focuses only on the form of the media, not the content or the encoded message and its interpretation. In contrast, coded visualization is not characterized by data types (e. g., numerical or text), representation techniques (e. g., bar, line, pie, map), or interaction features (e. g., filtering, highlighting, zooming). Instead, coded visualization covers the diverse possibility at each design space: the origin of data, the volume and organization of the data, the level of abstraction in the representation, the amount of interactivity with their audiences, and the methods of distribution and exhibition. Moreover, as I identified earlier, coded visualization has the following distinguished concept: a data-based interface, form as an aesthetic space, computationally coded messages, and cultural interpretation.

I also clarified the rhetoric and aesthetics of data visualization that were driven by computation. To sum, as the new rhetorical phenomena of computational visualization, I articulated as follows: users' creating and gathering data, experimental forms by digital production, interaction for further exploration, procedural rhetoric through dialogues, off-visualization engagement, and coherent identity throughout multiple platforms. The new aesthetics were characterized with the followings: encyclopedic cultural contents, variable forms for modular data, pre-designed forms, direct visualization for cultural visual media, interaction bridging functionality and storytelling, and platform for secondary data exploitation. In fact, these features of the rhetoric and aesthetics of coded visualization correspond to the five design spaces—resources, contents, form, interactivity, and platform (Table 1). Integrating and reflecting the essence of these theories that I have built, I suggest five design criteria along the design spaces (Table 2).

These criteria are the representative characteristics of coded visualization that are distinguished from other types of visualization. In other words, as the abstraction of the features of coded visualization, each of the criteria is not a strict guideline that has to be fully met in designing coded visualization. I argue that if a visualization project does not follow all of the criteria can be still considered coded visualization as long as it fulfills other qualities sufficiently.

Table 1. Design spaces and matching the new rhetoric and aesthetics

Design Spaces	**Rhetoric/aesthetics of computational visualization**
Resources & Contents	Users' creating and gathering data
	Encyclopedic cultural contents
Form	Experimental forms by digital production
	Variable forms for modular data Pre-designed forms Direct visualization for cultural visual media
Interactivity	Interaction for further exploration Procedural rhetoric through dialogues
	Interaction bridging functionality and storytelling
Platform	Off-visualization engagement Coherent identity throughout multiple platforms
	And platform for secondary data exploitation

Table 2. Design space and matching design criteria of coded visualization

Design Spaces	**Design Criteria**
Resources	Participatory and mash-up cultural data
Contents	Disagreement and conflict in contents
Form	Cultural references into computational forms
Interactivity	Interaction for narratives and provocation
Platform	Proximate to current civic events and issues

5.3.2.1 Participatory and mash-up cultural data

In contrast to the other types of visualization that utilize existing data, coded visualization allows people to generate their own relevant data. Such people-generated data involve two cases. One is that people are not aware that their actions would be the sources for visualizations. The other one is that people are actively and consciously involved in creating data that will be represented in visual forms as a manner of seamless experiences or later.

Opportunities of the unaware resource generating for visualization are found in the collective data from numerous Web 2.0 based social network services such as Twitter, a micro-blogging site and Instagram, a photo-sharing site. The text and its accompanied images and URLs from each tweet on Twitter are used for many visualization projects, beyond the real-time interface on Twitter site and other third party applications. Instagram has gained much attention from data analysis and visualization researchers. Besides such services whose contents are originated from their own users, user-generated commentaries to traditional information-rich venues can become data resources. For example, readers' comments on the articles on NYTimes.com can be retrieved using is Community APIs.

There exist several visualization-based projects that allow people to input data as a form of commentary and show the immediate presentation of the accumulated data. Data resources can span from a single user's responses to specific questions on a website to a collective database regarding on a timely issue. I revisit two examples introduced earlier in this thesis; on *VoteEasy* (Figure 7), a user can get advices on elections through a series of visualization that are prompted by her or his answers to the questions on the site; on NYTimes.com users can leave their thoughts on Osama bin Laden's death and see the collective responses through a seamless transition on a same interactive visualization (Figure 29). However, there are not many visualization-rich sites that enable data collection and consequent visualization in a seamless and real-time manner. Still, for the immediate display of updated data, most social network service websites show the users' data into a form of chronological text-based listing.

5.3.2.2 Disagreement and conflict in contents

The raw data generated from people's participation will be collected, sorted, filtered, and mined to become datasets that can be immediate sources for visual mapping. This wide range of such user-generated data can be accessed freely with limitations to some extent using various APIs. At the phase of retrieval, creators can choose the subset of the raw materials according to their intentions and research questions. For example, Hochman and Schwartz (2012) used Instagram (http://instagram.com) and gathered around 550,000 photos with location tags as New York and a similar number of photos with Tokyo. With a method of cultural analytics, they performed a comparative study to observe some cultural patterns of these two cities.

Similar to the comparative visualizations from cultural analytics and text analytics, but to emphasize its rhetorical purposes of visual media, coded visualization can collect, filter, and mine the raw data to more extreme level resulting in the explicit disagreement or conflict in the processed data. In addition, diverging contents can happen at the phase of interactivity among the design spaces; the designers of visualization can provide some interactive menus that lead to manipulating the data and images. These additional features can allow users to visually investigate the possible conflict in the data. For instance, *We Feel Fine* has a view called "Mobs" that is a visual analytic interface rather than a pure representation of the entire dataset. In this view, users can organize the data according to various dimensions including the words of feeling, gender, age, weather, and geographical location. As observing the breakdown of the data, users can learn the contrary data distribution by the dimensions (Figure 50).

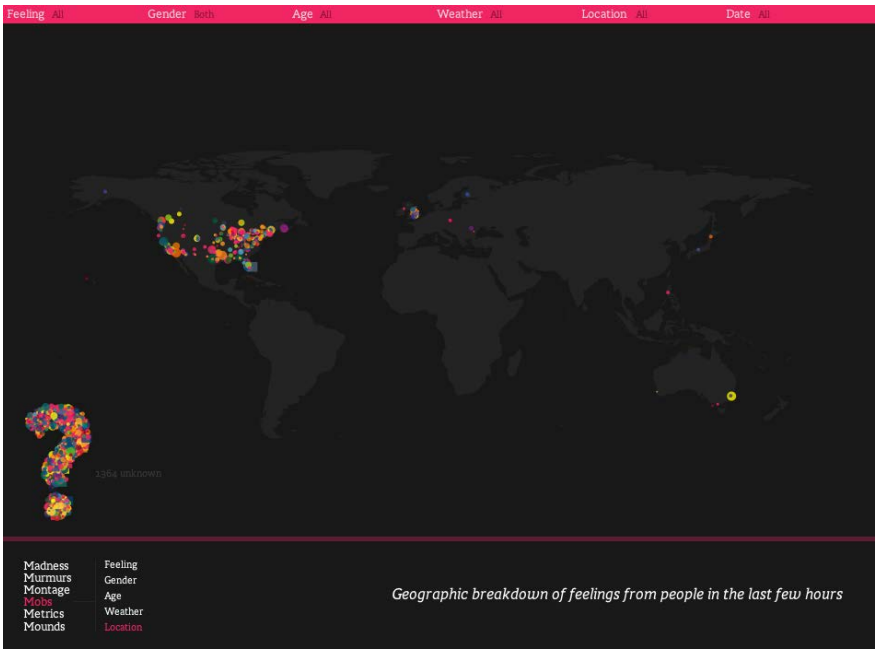

Figure 50. Geographic breakdown of feelings, triggered by users' self-sorting. (http://www.wefeelfine.org/common/movements/mobs-locations-full.jpg)

5.3.2.3 Cultural references into computational forms

One unique aspect of coded visualization is that it can be freed from the strict and minimalism-influenced principles of visual mapping that praise the universal and unbiased coding. This loosened rule of data encoding does not mean that it allows false data encoding tricks that have been used to deliberately deceive viewers but enables the encoded visual elements to be interpreted with cultural references. Specifically, colors can be used according to the cultural conventions. For example, red is used for the Republicans whereas blue for the Democrats as seen in the Obama chart (Figure 2).

I also argue that coded visualization can be liberated from Tufte's criticism of "chart junk." I do not advocate that the drawing-heaving additions to data charts should be the central part of a visualization as a visual media. Instead, designers could enhance the visualizations with culturally relevant visual elements for rhetorical and aesthetic purposes beyond the efficiency for information delivery. Many successful infographics

projects by graphic designers meet the safe balance between the minimalistic visualization techniques and decorative additional elements to the initial chart forms.

5.3.2.4 Interaction for narratives and provocation

Designers may insert interactive cues onto the surface of the visual forms that allow a limited number of forms of navigation. The ways of navigation are devised based on the various combinations of the dimensions of the represented datasets. Interaction in coded visualization is not appended only for the inclusion of more dimensions of the datasets. More importantly, interactive elements of coded visualization work as a user-driven interface for the further navigation of the data and the represented visual form.

Navigating the data-based interface not only supports the visual analysis of the contents but also brings opportunities for rhetorical interpretation in the visualization as an aesthetic sphere. Through exploring with different interactive features, users can discover insights and generate stories that were either intentionally devised by designers to be found or dependent on the users' self-exploration and interpretation (Hullman & Diakopoulos, 2011). Beyond a narrative-generating tool, interaction within a visualization can even provoke further social and political discussions of a relatively more serious issue. As exemplified earlier in a visualization showing the unemployment rates of different races, gender, and educational backgrounds (Figure 32), a user can investigate the dramatic change of the rates among different social groups through simple sorting options. This interaction results in a visually striking animation depicting the change of numbers, and eventually can be reasonable evidences for further political debates.

5.3.2.5 Proximate to current civic events or issues

Visualization focusing on the presentational purposes, which is usually labeled as causal visualization or narrative visualization, has become ubiquitous enough to be accessible in the numerous forms of digital media such online news and mobile applications. Such expanded context of the exhibition allows people to have more chances to interpret social topics encoded in a different from than text.

In this criterion, "proximate to current civic events or issues," I do not only include the methods to share visualizations but extent to the temporal context that can spark the discussion around data and visualizations. This contextual characteristic of coded visualization explains the timely designed visualization projects that are exhibited through online news media and visualization blogs. Numerous visualization projects are introduced targeting a specific civic event such as an election or a bill pass; this is a social phenomenon not only by major media vendors such as NYTimes.com but also by individual graphic designers. Such visualizations maximize the easily accessible platforms for visualization exhibition and distribution.

5.3.3. Examples of coded visualization

I introduce the five criteria as a set of features of coded visualization that emphasize the new aesthetic and rhetorical opportunities of visualization. As explained earlier, these criteria do not work as strict design criteria all of which must be fulfilled in designing coded visualization. For instance, even if a visualization work does not allow an on-site data creation of the users, it can be considered a coded visualization as long as it fully satisfies other criteria such as provoking intense social and political discussions with aesthetic forms and interactive features. Here I present several visualization projects

that I identify as coded visualization, for the better understanding of applying the criteria to analyzing and designing visualizations. I illustrate how these visualizations exemplify some parts of the criteria although they do not satisfy all of them rigorously.

5.3.3.1 Reconstruction2012

Reconstruction2012 (Pennebaker & Chung, 2012) analyzes the three U.S. presidential debates in 2012 and displays the results of analysis through experimental typography and data charts. Since the resource of this web-based application is the textual script of the two candidates' debates, it focuses on the *unequivocal contrast between the conflicting entities*.

After choosing one of the debates, it shows the transcript of the candidates in the real-time speed. Some words of the scripts are highlighted if they are about facts, figures, and emotional outbursts with different background colors (Figure 51). In the transcript view, the text visualization follows *conventional typographical devices* such as limited mix of different typefaces and font sizes. The text layout in columns is not far from typical editorial design principles; Obama's script is in the left column, Romney in the right, and moderator in the middle. These cultural references of typography and layout design are well appropriated in this unique form of animated and dynamic text visualization.

Several key words are also highlighted (using underline), and clicking one of these switches the view to the list of the most frequently used words. In parallel with the textual analysis, this application shows the statistics of the results in several pieces of data visualization (Figure 52). It analyzes the languages used in the debates, and

compares the results from the debates of previous elections. The transition between transcript and stats allows the immediate analysis of what the two candidates are saying.

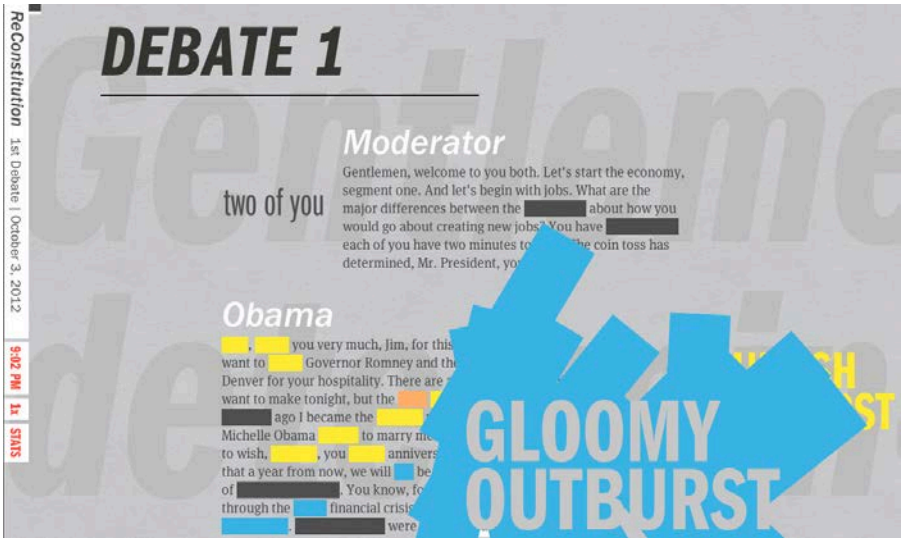

Figure 51. Transcript view ((http://www.recon12.com/)

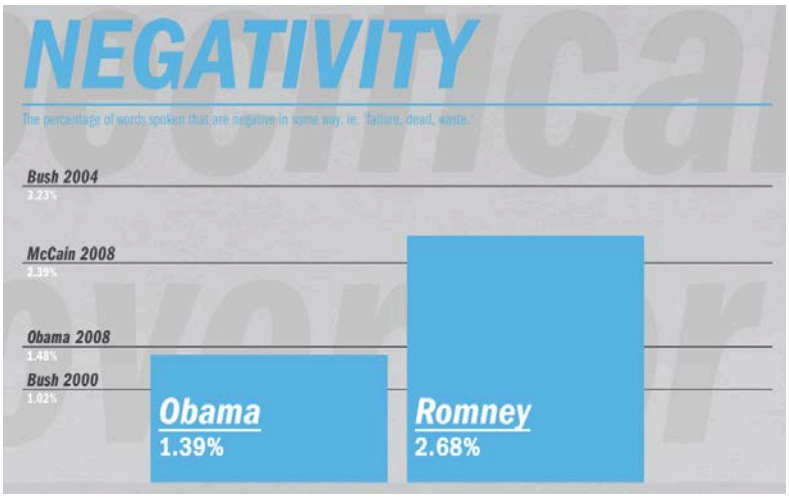

Figure 52. Stats view, data visualization of the negative words used in a debate (http://www.recon12.com/)

5.3.3.2 Home and Away: Iraq and Afghanistan War Casualties

The cultural data of this visualization project by CNN are about the people who died in the wars in Afghanistan and Iraq from 2012 to today (Figure 53). Focusing on each individual of total 3,264 and 4,804 deaths in Afghanistan and Iraq respectively, this visualization shows the detailed information of the dead person—name, picture, reason of

casualty, and more centrally the places of birth and death. Since the data itself are drawn on *the political issues of intense controversy and conflicts*, visualization as another way to depict the resources cannot but convey profound critical deliberations. As the visualization is continuously updated, it targets an *ongoing political issue,* not a single event.

Besides the intensity of the resource, the way that a user interacts with the visualization can *provoke emotional responses*; linking the birth place of the dead people and the death site reinforces the cruelty occurred in the visible geographical distance. When a single person is selected, the visualization is switched to a memorial page devoted to the person where visitors can leave their memories with him or her. This visualization project exploits the conventional visualization techniques such as map, bubble chart, and bar graphs over timeline, and the interactive features are typical. However, by combining these familiar ways of visual and dynamic presentation into the side-by-side views of the tragic contents strongly affect the emotional aspects of the users.

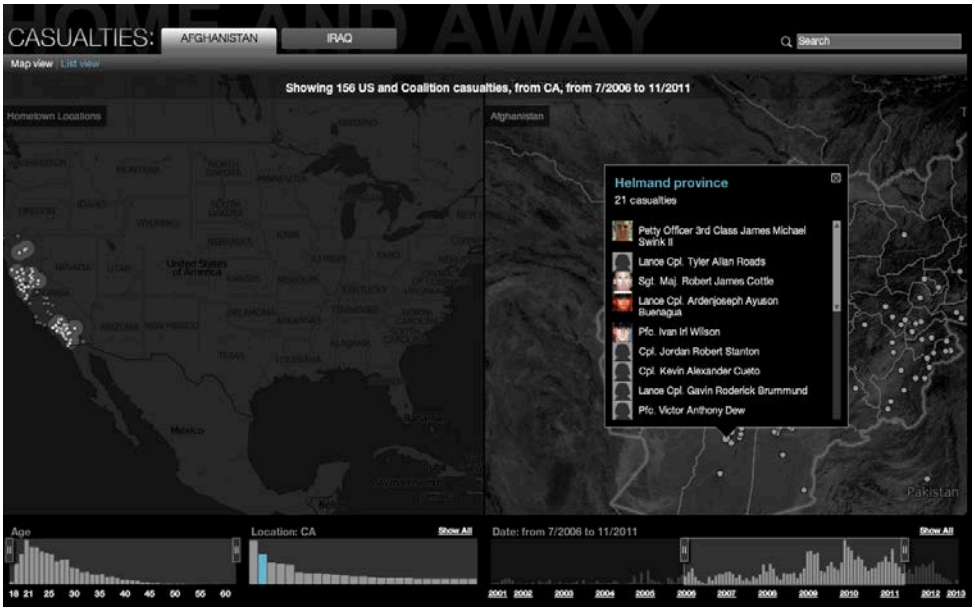

Figure 53. Visualization showing the birth and death place of people during the Afghanistan war (http://www.cnn.com/SPECIALS/war.casualties/index.html)

5.3.3.3 The NameVoyager

The last example is *The NameVoyager* that has been one of the most popular visualization-based website since its release in 2005 (Figure 54). As claimed in an academic paper about the project (Wattenberg, 2005), this visualization represents "social" data that is the historical trends in baby naming. In the developer's original argument, these data are social because they can spark both online and real-word discussion about names with other people. Besides such social effects, I argue that these data are also *cultural* although baby names are apparently much less political than the data used in the previous examples. Baby names are cultural because when parents choose their baby's name they are much affected by the geographical, temporal, ethnic, and religious contexts.

The NameVoyager exploits a common and straightforward visualization technique, stacked graphs for a given set of name popularity time series. The chosen colors reflect the *contemporary western custom*, sky blue for boy and pink for girls. The various user types of this site according to the purposes of use—achiever, socializer, explorer, killer (Wattenberg, 2005)—indicate that this site can be used for *storytelling* and even *entertaining* beyond finding facts about the names.

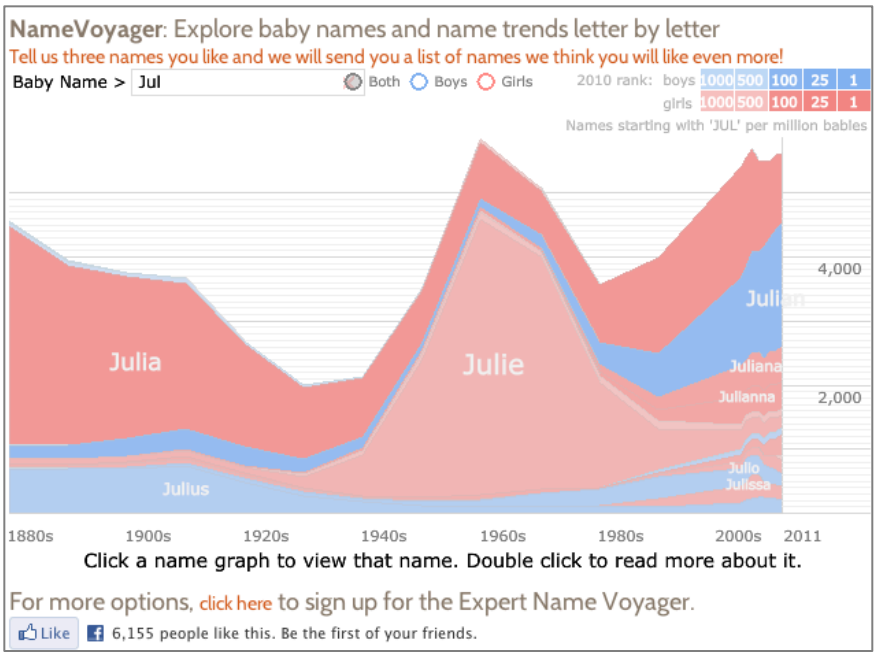

Figure 54. The historical trend of baby names starting with "Jul" (http://www.babynamewizard.com/voyager)

As a final theoretical part of this thesis, I synthesized the discussions on rhetoric and rhetoric of data visualization into a new term, coded visualization. I distinguished coded visualization from other types of visualization with its role as a cultural interface. At last, I suggested a set of criteria applicable to the design of a data-based cultural interface. The design criteria of coded visualization do not aim at specifying the types of data, representation and interaction techniques, or particular social media for exhibition. Instead of the technical restriction of implementation, the criteria focus on the potential of expressing and exploring cultural data and the subsequent social impacts. In the next chapter, I attempt to apply these criteria to a design research project and discuss how they can be used in designing coded visualization.

Chapter 6

The Political Grid Project

In the previous three chapters, the theory part of this thesis, I discussed the rhetoric and aesthetics of computational visualization and synthesized the two aspects in one new term, coded visualization. As the last part of theorizing coded visualization as a subject of design research, I also suggested its design criteria. In addition to the theories, this chapter is the practice part of the thesis, in other words, "research through design."

I apply the design criteria, which are derived from the theories on rhetoric and aesthetics of computational visualization, to a design project called "The Political Grid Project" that aims at social expression through a seamless process of visualization. I discuss how the design criteria are used in designing this Twitter-based website: design decisions, challenges and technologies. After the release of the site to the general public, I observed how people participated and used this site. With the description of the users' participation, I critique the project focusing on how thoroughly the design criteria were exemplified or not, and discuss how to enhance the site for the better example of coded visualization and a medium for political expression and its analysis in general. At last, I suggest further design practice agendas in the realm of coded visualization research—interactivity of visualization beyond WIMP-like interface, more critical and provocative approach that even can break the ground of objectivity and truth of visualization, and a unique form of participation that is specific to visualization media in digital environments.

6.1. Background: Twitter as a public sphere

Design practice is one way of my research methodology. For this, I first tried an existing media that could be the foreground to apply the design criteria of coded visualization—cultural data, conflicting contents, forms with cultural interpretation, critical interfaces, and relevance to current social issues. After reviewing several existing technologies that enable the public to exploit existing data from social network services, I finally chose Twitter (http://www.twitter.com), which is a micro-blogging site. It works as both a social network service and a news medium (Kawk, Lee, Park, & Moon, 2010), and it becomes one resource of our data. The important technological base that we exploit is its APIs. Twitter provides the general public with open APIs that allows third parties to retrieve the text-based twitter data with additional meta-data and attributes. In this section, I describe the context how this social media and news media can be used for civic agendas and the goal of the projects.

6.1.1. Social influences of Twitter

Twitter, the most popular micro-blogging service, enables people to post (i.e. “tweet”) their thoughts, feelings, news, and opinions within 140 letters that are often accompanied with pictures and geography tags. Due to its simple mechanism, ubiquitous access through multiple platforms and fast information sharing, Twitter has become a crucial medium for the contemporary politics. Twitter has been actively used as a news and promotion medium by politicians, activists, and media outlets. Politicians and political parties take advantage of Twitter to spread their voices. So do journalists and their news channels to response to these voices and drive the public’s opinion.

As Twitter became a unique type of social media, the data generated on Twitter are also a unique and interesting resource for research in social sciences (social media studies (e.g., Golbeck & Hansen, 2011), journalism, and public policy) and engineering (data mining and information visualization (e.g., Heer & boyd, 2005)). Many social media and HCI researchers have investigated the nature of its social networks and the value of the data generated in the Twitter sphere. Researchers in these fields exploit the data to discover insights about human behavior and social networks that are politically meaningful. Through complex qualitative and statistical methods, these projects demonstrate that Twitter can be a barometer to predict diverse phenomena in the creation of public opinions and the effects on related political events.

One research reveals that Twitter users are following or followed by other users who tend to have similar political stance (Golbeck & Hansen, 2011). The researchers conclude that people who follow Congress people on Twitter may be politically savvy resulting in more polarized political tendencies than the overall U.S. population. Another research validates that Twitter can be used to predict the election results. The ranking of number of tweets containing a party name equals that of the actual voting results (Tumasjan, Sprenger, Sandner, & Welpe, 2010). Through the sentiment analysis of the text, they also find the possible coalition between candidates and parties. To be specific, the similarity of the political parties' profiles is indicative of their proximity. Golbeck and Hanseh (2011) investigate political preference among Twitter followers by analyzing three different types of interactions on Twitters that are retweest (followers can duplicate their followees' tweets to broadcast to their own followers), mentions (tweets can indicate user accounts appending "@", often as a reply directly linking to an older tweet) ,

and hashtags (people append "#" to promote a specific keword); the network of political retweets exhibits a highly polarized partisan structure, with extremely limited connectivity between left- and right- leaning users. In contrast, mentioning, user-to-user network is dominated by a single heterogeneous cluster in which ideologically-opposed individuals interact at much higher rate. Users who apply hashtags are more likely to engage in communication with opposing communities.

Besides these academic research projects, many third party applications exist that focus on the Twitter users from politics and journalism in the vast Twitter-sphere. For example, before the presidential election in the U.S. in late 2012, several websites utilizing Twitter data opened. A website called *We Follow* shows the lists of influential Twitter users including a category of politics (Figure 49). *The Washington Post* has a page that shows the list of potential candidates with the number of Twitter mentions. Focusing on a single candidate, the page also shows the temporal trends of the mentions (Figure 50). *2012twit* (http://2012twit.com) was a temporary project retrieving the tweets from the major candidates and visualize several simple statistics of the data (Figure 51). These sites show influential Twitter users based on the number of followers and tweets that are freely acquired through Twitter APIs. Additionally, the APIs enable users to retrieve data about the spread of a single tweet including the number of re-tweets and replies.

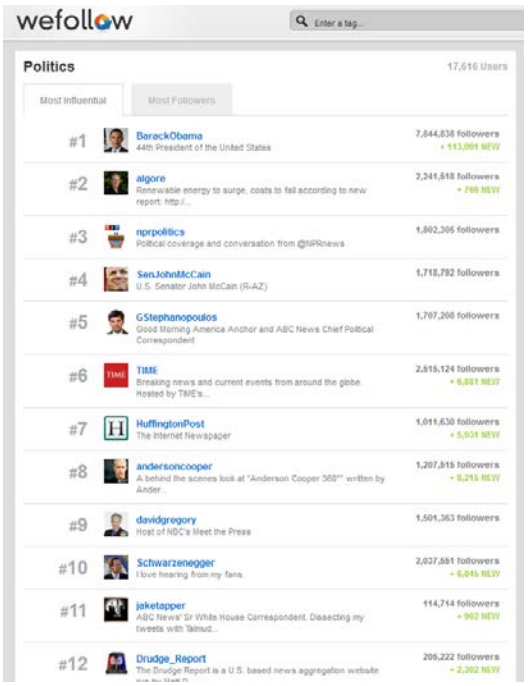

Figure 55. List of influential politics-related Twitter accounts at wefollow.com

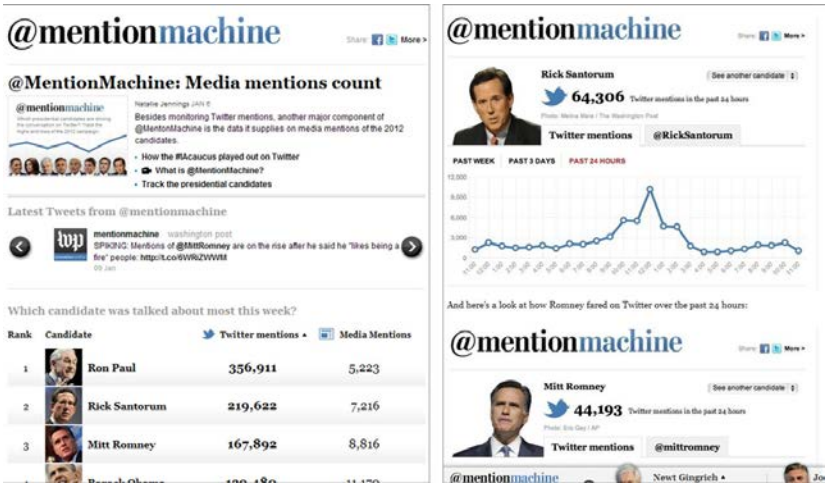

Figure 56. Mention Machine

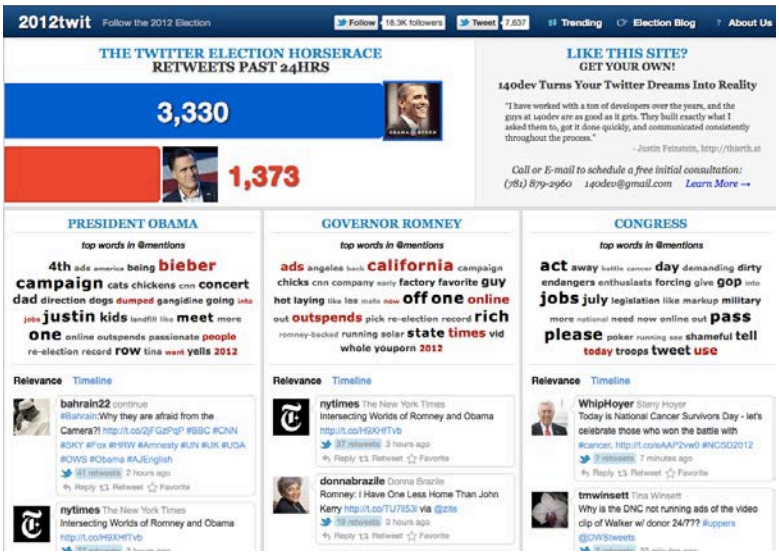

Figure 57. 2012tweet: Follow the 2012 election (http://2012twit.com)

6.1.2. New Approaches to political engagement and expression

The approaches of third-party applications are the re-presentations of the existing Twitter data without people's participation. Moreover, research projects are concerned mostly about the academic achievement validating their statistical analysis methods. The original Twitter system and its current applications might have limitations for the actual engagement in the political issues and the expression of political opinions. Here I articulate the current problems and our design goal to tackle these issues.

First, the simple re-presentation of existing Twitter data seen in the previously introduced applications does not encourage the onsite political expression. Roughly speaking, the influence of the Twitter users can be estimated by the number of tweets and followers (subscribers of a user's tweets), because Twitter users follow other users who interest them in terms of the quality and immediateness of information they deliver. Focusing on a single tweet, the number of retweets and replies can be a parameter of the popularity and importance of an issue in a timely manner. However, these simple

descriptive numbers do not necessarily present the “true impacts” of the tweet, and furthermore those of the user and what he or she has been saying through tweets.

Second, according to the political polarization of Twitter users’ social network (Golbeck & Hansen, 2011), the information obtained from followings may be limited and even biased even though Twitter is the resource to earn political issues in a very fast manner.

The last limitation of Twitter as a steady medium for journalism is caused by the promptness and short lifespan of tweets. Twitter users mostly read tweets on Timeline that broadcasts the tweets from all of their followings in real time. Thus, the tweets are meant to be extremely ephemeral and users should use different navigations to read relatively old tweets.

To overcome these limitations, I design a Twitter-based website in which people can express their opinions beyond the action of replying or retweeting. The new approaches also in align with the design criteria of the coded visualization that I suggested earlier. Largely, three factors differentiate my project from the other applications and projects that I presented earlier.

First, I design a new interface to let people express how they really think about politically influential tweets. The site lists tweets posted by political entities, and a user *votes* on each tweet based on the two standards—*how much she agrees with the idea expressed in the tweet, and how important it is to her*. This onsite participation allows me to collect additional data besides the open data from Twitter. Second, users will examine the politically influential tweets selected by the system, not the real time stream of their followings. In this way, they can have chances to see the tweets by politicians or parties

that they do not follow. Third, I do not let tweets flow fast, but make the most voted tweets accessible. In doing so, I expect users to actually think about the messages in the tweets, not simply scan them.

The more important and distinguished feature of *The Political Grid Project* is the visualization of the collected data. The site provides users with various interactive visualizations that represent both individual and collective voting data accompanied by data from Twitter. The aggregation of the generated data as political opinions is the useful resource for the further data analysis. The analysis results do not stay in the researchers' laboratory but open to the users as a series of interactive visualizations allowing their self-investigation. To my knowledge as of early 2012, there were no Twitter applications that enabled end users to create new types of data, which could explicitly express the users' opinion, besides consuming and adding to Twitter's database. In the next section, I articulate how these features our project are exemplified in line with the design criteria of coded visualization.

6.2. Designing coded visualization

Twitter is a social medium that attracts researchers who investigate diverse political phenomena online and seek for the indicators to understand real world events from the virtual world. Beyond this role as a research tool, I retrieve data from Twitter, and provide people with more spaces where they can actively express their opinions by creating their own data. Eventually I let them engaged in the political issues through visualizations of the data. With these goals, I design a visualization-centered website named *The Political Grid Project*. On this site, the general public can create new datasets through voting on the retrieved tweets, and investigate the data through diverse

visualizations. In this section, I describe the design specifics by linking to the design criteria of coded visualization (user-generated cultural data, disagreement and conflict in contents, cultural references into computational forms, interaction for narratives and provocation, and proximate to current civic events and issues). First, I introduce the technologies used to develop the site and the challenges in the implementation. Next, I discuss the characteristics of this site in regards with the context, data creation, and the visualization of the data.

6.2.1. Technology and site structure

The Political Grid Project enables the general public users to create new datasets additionally to existing Twitter data. For this, first I retrieve data using the APIs that Twitter provides. The site has several pages that load new tweets obtained with these APIs. I developed the website with PHP and utilized CSS and jQuery for the dynamic user interface and cross-browser/platform support (Figure 58). In addition, in order to collect users' voting data, I built a database using MySQL. In the database, I set up tables that contained the following information:

- Voices: Politically influential Twitter users (Twitter ID, name, screen name, profile picture URL)
- Citizens: Twitter users who signed in our site and vote (Twitter ID, name, screen name, profile picture URL, voting count)
- Tweets: Voted tweets (Voice's Twitter ID, Tweet ID, post date, and the text of Tweet)
- Votes: All the votes done by the citizens (Tweet ID, voting citizen's Twitter ID, voting time, and the voting points of the two standards)

To use *The Political Grid Project*, a user should sign in with his or her Twitter ID, not separately register a new account on this site. One advantage of using twitter ID is that I can track each user's activities and earn their meta-data from Twitter. Also, "sign in with Twitter" implies that this site is a third party Twitter application, which results in a sense of security and trustworthiness. Information about the users including their Twitter ID, name, screen name, profile picture URL is stored in the database of the site, once they authorize to access their Twitter account. The consent information is provided before they sign in with their Twitter IDs, and they have to agree to the information in order to proceed to use the site without limitations. Users can look around the site without signing-in, but they can neither vote nor examine the voting results of each tweet.

The website largely has two menus—"Vote" and "Visualize." "Vote" is a space where users read the tweets and vote on them. "Visualize" shows the results of the voting through various types of visualization. The detailed description of the visualizations will be followed later. Once a user signs in, he is directed to the voting page. The voting page shows the tweets by the two major candidates in two columns, so the users can see the list of tweets side-by-side in real time. In other words, the newer tweets are listed earlier in the list same as the original timeline at Twitter.com. Another option to sort the tweets is the voting counts. This sorting allows users to examine which tweets have gotten most attentions.

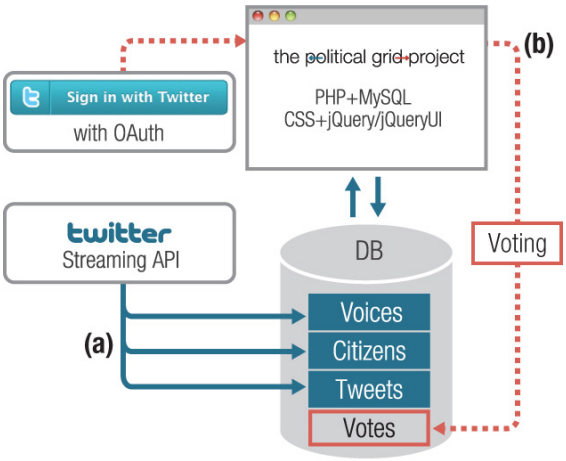

Figure 58. System of *The Political Grid Project*: data are collected from two sources, (a) Twitter APIs and (b) Sign-in users' voting.

6.2.2. Contrary contents from a major civic events

The last design consideration of coded visualization is "*proximate to current civic events and issues*" for the timely expression in regards with social issues. According to this condition, *The Political Grid Project* targets a major political event that covers the interest of a largest number of populations. This approach is often found in the previous social media research that focus on the use of Twitter on a specific natural catastrophe (Starbird, Palen, Huges, & Vieweg, 2010) or national-wide election. (Tumasjan et al, 2011). Luckily enough, 2012 was the year of the presidential election in both the U.S. and South Korea, so I decided to focus on the tweets relevant to this event. Focusing on a specific political event would make it more meaningful to compare voting patterns and results on the politicians and to track user behaviors within the project site.

The initial plan was to show more number of politically influential Twitter accounts including potential presidential candidates, prominent media vendors, and journalists. I began by retrieving the list of Twitter users that are influential on politics, specifically the U.S. presidential elections in 2012 from Twitter's own suggestions (https://twitter.com/#!/who_to_follow/interests/us-election-2012). I call these politically

influential Twitter accounts “Voices.” I also planned that the users of the site can also suggest other Twitter users as Voices. Once a newly suggested voice is reinforced repeatedly by other users, this voice will be included in the public pool of voices, so that all users can see their tweets and vote on them.

However, during the closed test with a small number of users, it seemed to be complicated to show multiple voices in one timeline, so I decided to focus on the two major presidential candidates (i.e., Obama and Romney in the U.S. case), so the users can focus on the two candidates at the same time and compare them side-by-side. In doing so, I can contrast the two entities more explicitly, which in fact fits better one of the design consideration—disagreement and conflict in contents (Figure 59).

The contrast in the contents is also enforced in two different contexts—U.S. and South Korea. I built two separate sites for the two countries (http://politicalgrid.gatech.edu for the U.S. and http://politicalgrid-kr.gatech.edu for South Korea). For the U.S. site, I chose Barack Obama, the candidate from the Democratic Party and Mitt Romney from the Republican Party. The screen names of their Twitter accounts are @BarackObama and @MirrRomney respectively. For the Korean site, I had chosen major two candidates who ended up earning 99.6% of the total votes. One is Park Geyun-hye from the Saenuri Party, and the other is Moon Jae-in from the Democratic United party. Each candidate has had her or his personal Twitter account (@GH_PARK and @moonriver365) for a long time. Additionally, her and his belonged party opened a “camp account” that tweets mostly the election related information. Thus, I decided to show both personal and camp accounts for each candidate, and the tweets by the camp accounts (@at_pgh and @mooncap1219) were listed by default.

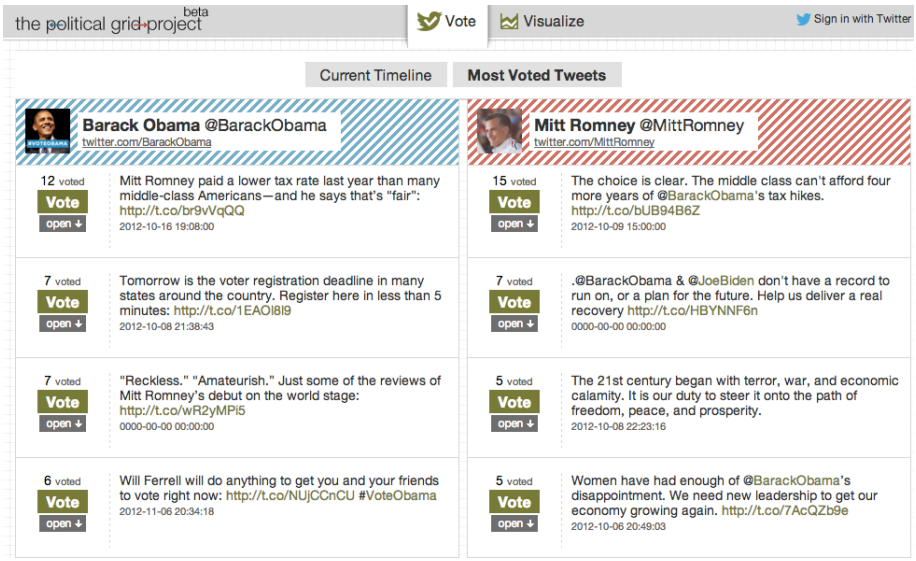

Figure 59. Tweets by two candidates on *The Political Grid Project*

6.2.3. Voting on tweets as computational comments

The core difference of *The Political Grid Project* from other Twitter-based applications is the fact that it enables users to generate additional data. This design decision is following the design consideration of coded visualization—*participatory and mash-up cultural data*. Twitter itself is a huge repository that contains diverse cultural aspects, but I open a space in which more data can be created. To highlight the features of this site again, I collect the additional data by allowing a user to vote on the individual tweets. The voting data becomes another set of cultural data, in addition to the existing cultural data being created through Twitter. This action gives users a chance to rethink about the messages in a further step and to express their opinions on them as *computational comments* beyond mentioning or retweeting that might be ambiguous in conveying the intention of those actions.

Voting is performed in the following simple step. The user is asked two questions—how much she agrees with the tweet, and how important it is to her—and she responds to those on a numerical grid (Figure 60). A user clicks on an intersection of the

"grids." Along X axis, he rates from -5 to 5 according to the degree of agreement with the tweet. Similarly, Y axis has the ratings for the importance of the issue. In fact, inferring this action of clicking on grid of political stance, I named the website The Political Grid Project. Furthermore, the word "grid" can remind one of a core idea of modern graphic design that is heavily influential on the aesthetics of contemporary computational visualization.

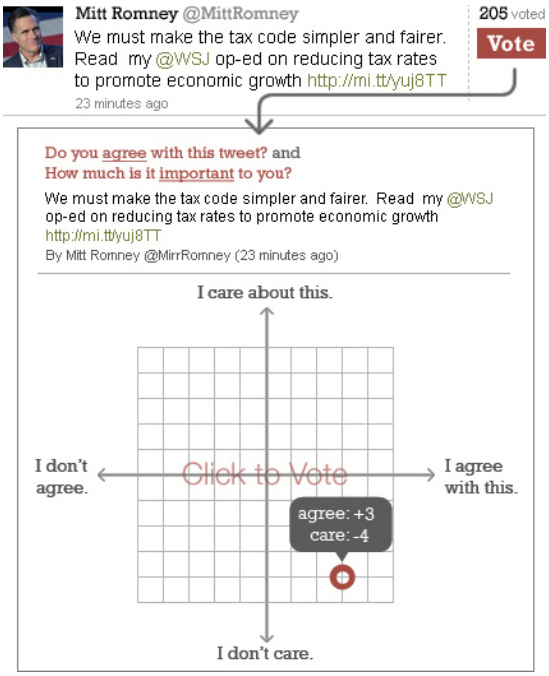

Figure 60. Voting on panel on a single tweet.

6.2.4. Visualizations of collective opinion

Two design criteria of coded visualization that are applied to the phase of making interactive visualization are *cultural references into computational forms* and *interaction for narratives and provocation*. In line with voting, engagement through visualization is another core experience in *The Political Grid Project*. Under the menu "Visualize," a series of interactive visualizations represents the diverse aspects of the data and allows users to investigate the data. At a micro level, a user can examine her political preference

and the voting results of each tweet or voice in a greater detail. At a macro level, I visualize all the votes of a single voice, used words in the voted tweets, and the temporal trends of voting. I discuss how the two design criteria are realized in the design of visualizations.

The current trend of visual design of social network services pursuits a simple layout, a minimal variety of typography, the logical use of colors, and the limited use of images. Many libraries that have CSS (Cascading Style Sheet)-based components and standardized interaction enabled by JavaScript or jQuery also contribute to this simplified and anonymized design. Overall, this visual style itself is rational and logical for the effective communication. The core technology used for the visualization design is D3, a JavaScript-based library for transforming data to graphical forms (Bostock, Ogievetsky, & Heer, 2011). Using this library, it is easy to implement the simple visual style. *The Political Grid Project* mainly follows this universal trend of web design since it targets the general public and utilizes an existing social media data, Twitter. Thus, I planned the visual style to look familiar but unique enough to be distinguished from the original Twitter website.

The art direction of the site including contents layout and colors also focuses on one design consideration—*disagreement and conflict of the contents*. Since I choose two major candidates, the side-by-side contrast can be easily emphasized. To distinguish the two candidates, I applied the two colors that have represented the two parties—blue for the Democrat and red for the Republican, which is one way of encoding cultural references into visualization. The parties in South Korea do not have strong color association established for a long time, but during the campaign, they had chosen

distinguished colors and used them for all visual materials. I also use these colors (red and green) to contrast the two parties on *The Political Grid Project*. This color coding is a simple but explicit way to encode cultural refences.

First of all, after a user's voting on a single tweet, the results of all the users' voting on the tweet are immediately displayed in the automatically expanded panel under the tweet. I visualize the results on a 2D plane that looks same as the voting panel. On this newly appeared panel, the user's voting is highlighted as a red circle over the corresponding location of the grid. If there are votes from other users, gray circles are displayed on the points of their votes (Figure 60). In addition, to advertise this site, I added a button to tweet about this vote in the expanded area.

The default page of the menu "Visualize" includes the visualizations of the all voting data of the two candidates (Figure 62). Each candidate has three different kinds of visualizations. First, bar graphs present the average "agree" (how much users agree with a tweet) points and "care" (how important users think about a tweet) points of all the voted tweets. Second, the average points of each voted tweet is represented on the plane that is same as the voting panel. The number of voting is encoded in the shade of gray; the more votes, the darker gray. Third, frequently used words in the voted tweets are presented in a Wordle style. I used D3 Word Cloud Layout Javascript library to calculate the size and position of the words. Since Korean language and scripts have different linguistic structures, the Korean version site does not have this text visualization.

On the other subpages of "Visualize," I included single voice-centric visualizations. While adopting a line graph on a timeline, I presented the temporal change of the voice's voting results (Figure 63). This visualization has two timelines. The one on

the bottom covers the entire duration from the site launching and to today. The y-axis presents the number of votes on each tweet. The translucent grey area is a slider that is movable and expandable/shrinkable. The time period that the slider spans is presented in the upper timeline. The main timeline shows the average of voting results on each tweet: X axis for the original post time of the tweet, Y axis is the two average voting points ("agree" and "care") of each tweet. By default, only "agree" is displayed but the two points can be toggled. In addition, when a user moves a cursor over a bar, it shows the text of the corresponding tweet.

Lastly, users can also examine the voting results of other users. A subpage "Citizens" shows the list of all voters sorted by their voting counts. Clicking one of those citizens prompts to a page of showing the voting results of the selected user (Figure 64). The visualization is simple; two dots, each of which represents a voice, are displayed over the voting plane.

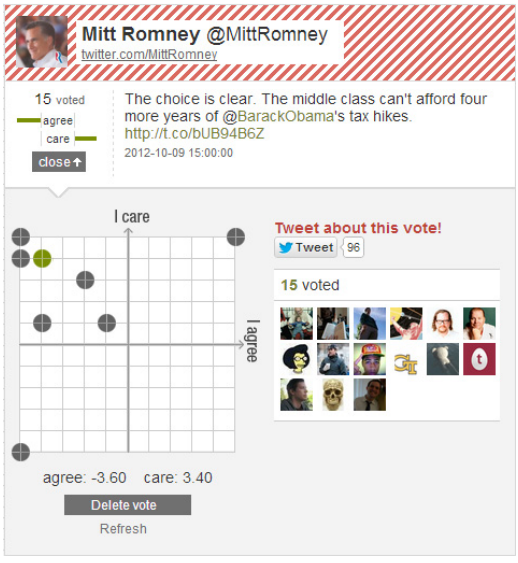

Figure 61. Results of voting on a single tweet

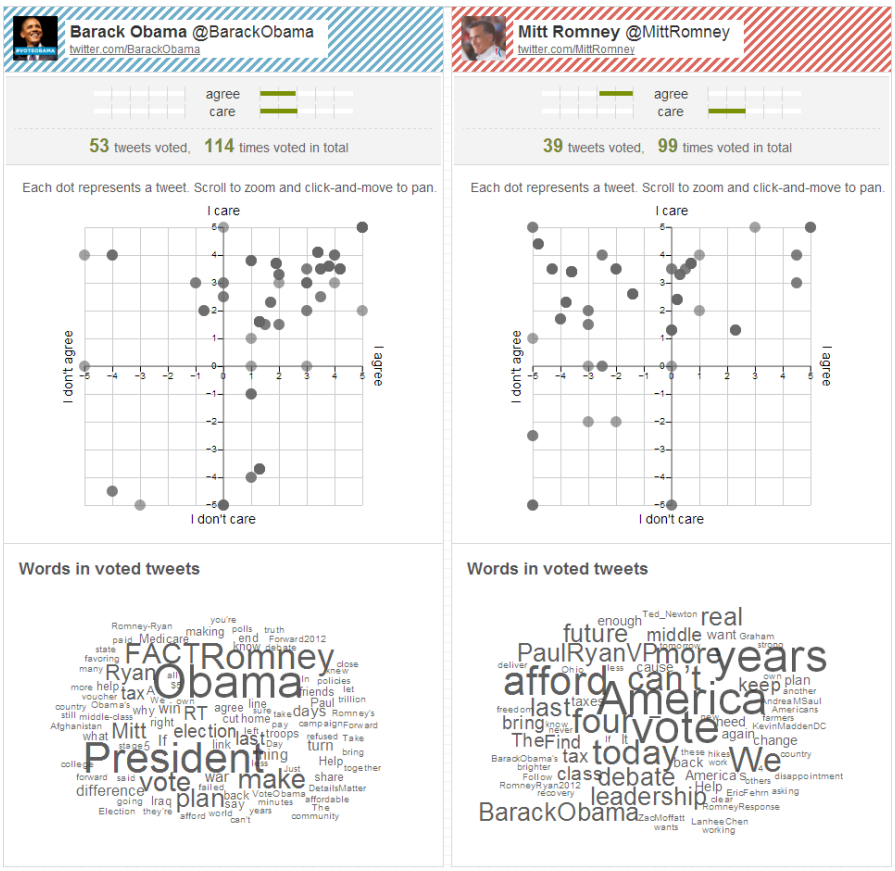

Figure 62. Comparative visualizations of the voting data

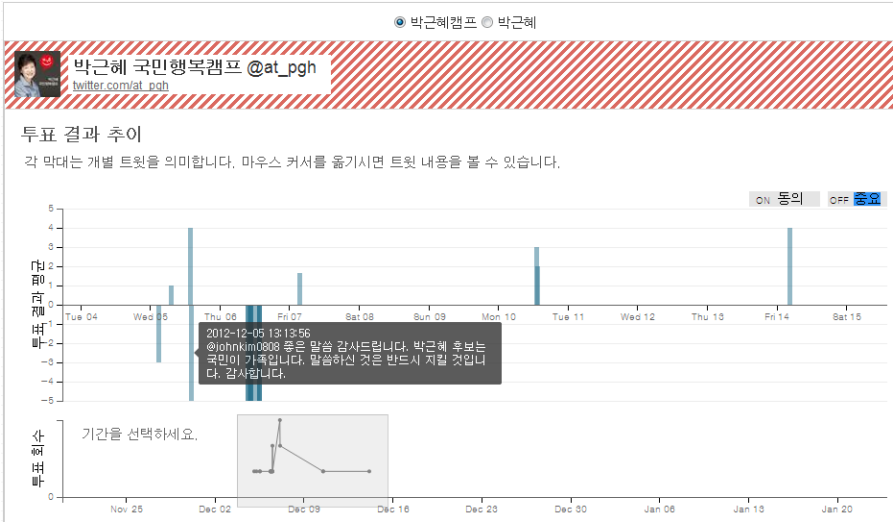

Figure 63. Timeline of all the voting result of a single voice

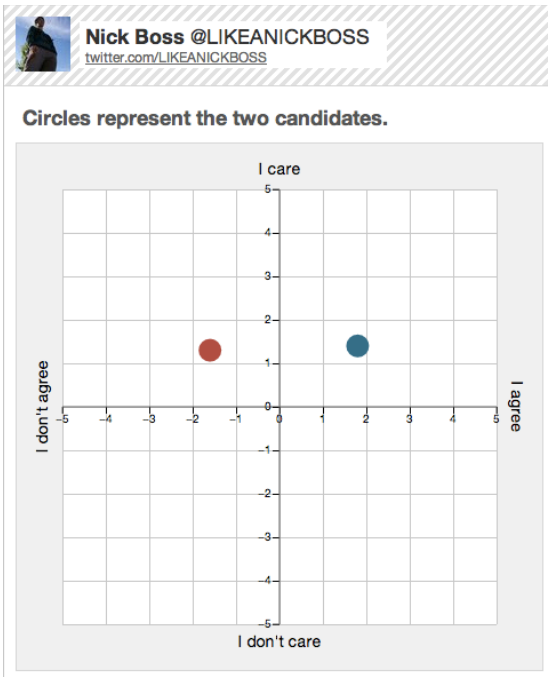

Figure 64. Visualization of the voting results of a single user

So far I discussed how I had applied the design criteria of coded visualization are applied to the specific design elements of The Political Grid Project. Here I generalize the design specifics according to the criteria (Table 3).

Table 3. The design criteria of coded visualization and the generalized design decisions

Design Criteria	**Elements**
Participatory and mash-up cultural data	Politically influential data from social network services Users' commentaries to existing cultural data retrieved in real-time
Disagreement and conflict in contents	Side-by-Side comparison of contrary entities
Cultural references into computational forms	Contrast colors reflecting cultural conventions
Interaction for narratives and provocation	Dialogues through data-generating activities Investigation of collective opinion
Proximate to current civic events and issues	Targeting an immediate civic event of a major interest

6.3. Discussion and critiques

This section presents how users participated in the two versions of the site. The goal of analyzing the user participation of this site is not predicting the results of election as other previous social media and data mining research projects pursued, but observing the users' characteristics reflected in their activities on the site. More importantly, I aim to critique how the design criteria are well applied to this design practice based on the observed user participation. I do not aim at evaluating the user experience with a traditional focus of HCI such as quantitative analysis of their behaviors on the site such as log analysis and surveys or qualitative investigation through interviews. It is because that this project is a practice of design research that harnesses its unique methods, not borrowing conventional HCI evaluation methods.

I also discuss the limitations of the sites and the aspects that need improvement found through the observation of users' behavior on this site. In addition, I discuss how the design criteria of coded visualization are reflected in the design practice, suggest better approaches to better pursue the criteria.

6.3.1. User participation

The presidential elections in 2012 were held on November 6th and December 20th in the US and South Korea respectively. I released the U.S. version site three weeks prior to the election date, and the Korean version two weeks. I used personal emailing lists and social networks including Twitter and Facebook (http://www.facebook.com) to advertise the sites. During the period until the election dates, eighty-seven Twitter users for the U.S. version, and sixty-one users for the Korean participated. Among those, thirty-eight and twenty-six people actually participated in voting at least once.

Many of people in my social networks on Twitter and Facebook are graduate students and professionals with higher education in their 20's to 40's, and I expected this educational level to be reflected in their activities on *The Political Grid Project*. The obvious anticipation is that the users of the site would be more preferable to the candidates form the liberal parties, because those who have post-graduate education tend to be more politically liberal. The actual participation of the users did not much differ from this assumption; Obama had more favorable results on "agree" level whereas the results of voting on Romney had more dispersed spanning from -5 to +5 of "agree" level (Figure 62). Users did not show different opinions on "care" level—they thought both Obama and Romney had talked important issues.

On the Korean site, the voting pattern was distinctive from the U.S. one. The candidate form the liberal side had positive responses on both "agree" and "care" levels. In contrast, the tweets of the conservative side are divided; some have higher rates on both "agree" and "care" levels, the others have negative responses on both (Figure 65).

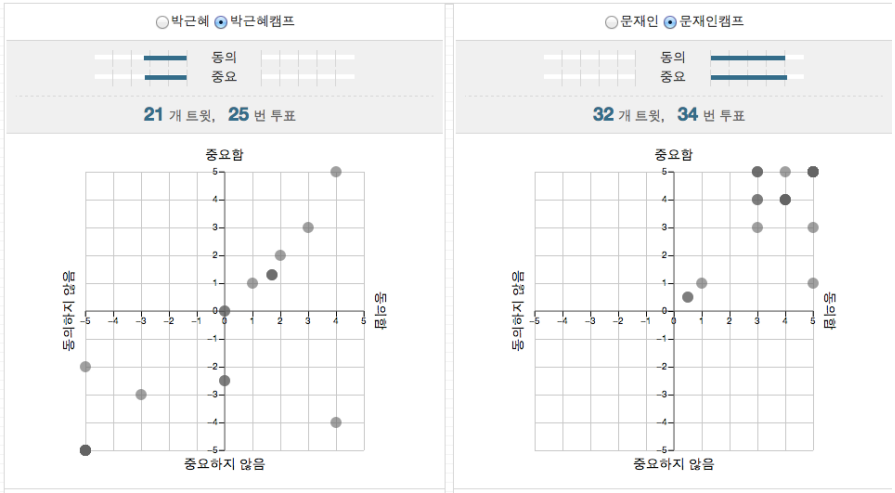

Figure 65. Voting results of the two Korean Candidates (left: conservative, right: liberal)

6.3.2. Rethinking the design criteria of coded visualization

Earlier I described how I designed *The Political Grid Project* according to the design criteria of coded visualization. After the running the site with the general audiences, I found several limitations and aspects that needed improvement. Here I discuss how each of the design criteria was implemented in this project.

6.3.2.1 Encouragement of participation

This project is distinctive that the data are collected from the two different sources. One is the politically influential data retrieved from the existing social network services, and the other is the user-generated opinion on those previously acquired data. After all, these two-layered data are cultural and political reflecting a current civic event. By providing a space where users can express their thoughts on the politically influential tweets in a different manner from Twitter's original communication methods such as mention or retweet, this site satisfies the first design consideration of coded visualization—*participatory and mash-up cultural data*.

The final numbers of the users who visited the two websites were not so large as I had expected. Here I discuss possible reasons and suggest better ways to encourage the participation. I did not use existing platforms but had to build a new website for this project. Thus I advertised this site in order to first make people visit the site. Then, I let them get involved in generating data on this site that has a fairly unfamiliar concept. I also found that not many users had not continuously visited the site and voted often. One reason might be the slowly updated contents, the tweets from the presidential candidates; even during the politically important season (i.e., two or three weeks before the election), there are normally less than ten tweets per day, and most of them were updated during the

day. Also, their Twitter timeline includes a good portion of retweets that are not retrieved into the site. Thus, even if users had frequently visited the site, they might not have seen new tweets to vote, which might have led to the less frequent and participation.

6.3.2.2 Presentation of contents for direct comparison

By choosing the major two candidates and showing them side-by-side, I intended to make the design consideration—*disagreement and conflict in contents*—more obvious to users. I argue that this consideration is the one realized most successfully on *The Political Grid Project*. The two-column layout for voting and visualization clearly contrasts the two competitive entities that show the dissimilar opinion. Due to the restricted demographics of the site users, the visualization as the results of their participations on the two candidates looks distinctive. With this comparative layout design and the consequent visualizations, users can focus on the entities of the most interest and compare them in an intuitive manner, especially when the decision time gets closer. Yet, I imagine that if the comparative visualization itself could highlight its different parts, users could find the starting point for the self-investigation more easily.

6.3.2.3 Cultural coding besides colors

For the visualization of the voting data in addition to the text data as the retrieved tweets, I used several conventional forms of data chart including scatterplot, bar graphs, timeline, and Word Cloud. I exploited these forms mainly because that I hoped that the users would understand the representation of the data without much cognitive load. For example, I applied the scatterplot form to several different kinds of visualizations including the voting results on a single tweet, the summarization of the all votes for each candidate, and the summarization of all votes of a single user. Also the scatterplot is

identical with the voting panel in which users create data. Through this consistent use of a familiar form for visualization, I expect users to quickly understand the presented meaning.

However, I acknowledge that these conventional forms might make the visualizations too generic to be a unique part of the project. Initially I proposed that the practice part of this thesis would pursue a position between “visualization practice” and “visualization exploration” in the triangular view of design research for visualization (Figure 17). Hence, the sole use of typical data chart forms without much visual enhancement for the aesthetic qualities may drive this project to the “practice” side more than “exploration” one.

6.3.2.4 Extensive navigation throughout multiple visualizations

When I implemented visualizations, I included several interactive features for the further investigation of the presented data. For now, each visualization has interactions within itself. Beyond this restrained interaction, multiple pieces of visualization can be connected through a wider plan of interaction that allows users to navigate the various parts of the entire data set in a seamless manner. For example, it is feasible to link the visualization of the average points of each tweet of a candidate (the middle part of Figure 62) and that of users’ summarized voting results (Figure 64). The former currently shows the number of votes that each tweet earned when mouse-over event is applied. Instead of the voting count, the list of the voters can be displayed, and each item of the list can have a hyperlink to the visualization of the corresponding single user. I expect this extensive navigation encompassing multiple visualizations can trigger the deeper investigation of data, which eventually lead to the further discussions and provocation.

6.3.2.5 Targeting a longer term of political issues

The last design consideration is "*proximate to current civic events and issues*" which concerns the temporal context and the situation of sharing. *The Political Grid Project* satisfies this consideration because it is specifically targeted the upcoming elections in two countries. The two sites were released close to the elections days, but this kind of political sites could benefit a longer period that involved proceeding procedures before the final election days. For example, the case of the U.S. presidential election, it can start with the conventions in which the candidate of a party is selected. Then it can track how the public opinions are merged or diverged throughout the entire process of the presidential election. In addition, a major civic event that covers a larger geographical area can show insightful differences among regions.

I close this section with a summary of the design criteria of coded visualization, the application of these to *The Political Grid Project*, and the possible improvement to better fit the criteria (Table 4).

Table 4. Improvement of the design project

Design Criteria	**Elements**	**Improvement**
Participatory and mash-up cultural data	Politically influential data from social network services Users' commentaries to existing cultural data retrieved in real-time	Exploiting existing platform for the larger participation
Disagreement and conflict in contents	Side-by-Side comparison of contrary entities	Highlighting conflict parts in comparative visualizations
Cultural references into computational forms	Contrast colors reflecting cultural conventions	Explorative and experimental forms appropriating conventional visualization techniques
Interaction for narratives and provocation	Dialogues through data-generating activities Investigation of collective opinion	Navigation crossing multiple visualizations
Proximate to current civic events or issues	Targeting an immediate civic event of a major interest	Targeting sub-events of a major civic event and consequent temporal/geographical analysis

6.4. Further design research agendas

At last, I suggest three possible further visualization research directions in regards with the focus of the thesis—the rhetoric and aesthetics of computational visualization. The three paths are 1) a more provocative approach of visual form that challenges the truth of data mapping, 2) narrative-rich interactivity beyond task-supporting graphical user interfaces, and 3) an environment for participatory commentaries unique to visualization. I describe each of them in a greater detail.

6.4.1. Critical design challenging the objectivity of forms

As I discussed the design criteria of coded visualization, I did neither ignore nor deny the primary definition and rule of visualization as a mapping of data into interactive visual forms. The coding should be mathematically correct, although the choice of visualization techniques might be subjective and conflict with the purity and objectivity of the data.

I envision that visualization could break this major proposition of correctness in the phase of mapping. This argument may appear to take aim at the core purpose of visualization. However, designers deliberately distort parts of visualization for aesthetic experiences that may even provoke users, not aiming at deceiving them. If a visualization system clarifies the intention of designers, the skewed aspects for visualization were devised in fact to gain higher trustworthiness and rhetorical interpretation, such InfoVis could be an alternative and experimental practices of visualization.

This approach, which provokes the primary goal of a system, is similar to para-functionality in critical design, an alternative lens to realize the aesthetics of electronic devices (Dunne, 1999). In visualization design, *cultural references encoded into computational forms* can make the visualization forms ambiguous to decode. This critical approach to designing coded visualization would be an interesting research, especially if a critical review is followed to assess the system, it can even start to establish a specific research interest.

6.4.2. Visualization as an immersive narrative space

The second further research agenda is designing visualization as an immersive narrative space. Some early genres of video games had very simple gameplay

mechanisms, such as hitting moving objects on a two-dimensional space. However, video games have evolved to offer a more immersive environment that embodies three-dimensional spaces, more complex interactivity in gameplay, and the consequent multiple and even encyclopedic paths of player-driven narratives. I argue that the state of contemporary visualization can be compared to such early types of video games. Even though presentational visualizations enable users to create their own narratives to some extent, the interactivity of most current visualization does not go beyond the roles of traditional graphical user interfaces typified as WIMP (Windows, Icons, Menus, and Pointer); the actions that users can take are limited to mouse control, and the feedback is the anticipated changes of images within a short time interval. Moreover, while devising the interactivity of visualizations, designers do not integrate complex rewards or penalty systems that are implemented in narratives-based video games. For now, I do not aim to suggest concrete forms of this procedural, immersive, and narrative visualization system. Yet I suppose that visualization as a unique digital medium can evolve as a persuasive medium with stronger narratives and even playfulness in a similar way as video game. Ultimately this evolution will fortify a design consideration of coded visualization, *interaction for narratives and provocation*.

6.4.3. Unique forms for user engagement

The last further research agenda is a unique form of participation for visualization-rich media. I stressed that the audiences of visualization do not stop at the phase of seeing and using the media. When people observe insightful aspects of the data or the interesting views of a visualization project, they often want to leave comments. A collaborative visualization system *Sense.us* suggests a type of visualization-specified

annotation interface; people can “bookmark” specific views of an interactive Infovis system with textual comments and a screenshot of the view (Heer, Viégas, & Wattenberg, 2007). I also witness several examples of media-specified commentary interfaces for another medium; on YouTube (http://www.youtube.com), people can leave comments specifying an exact timeframe within the video and the others can examine the moment. A streaming music publishing and sharing site, SoundCloud (http://www.soundcloud.com) also has a unique interface that people leave their impression on a specific moment of a played tune.

These examples encourage on-site participation, but now I can suggest future agendas for off-site engagement; what are the unique forms available to share a visualization and discuss it with other people? Furthermore, I can imagine that the commentaries attached to a visualization and other further traces of social action could emerge as a new dataset for the visualization or a secondary one. The new data would reflect the cultural and situated actions around visualizations. Furthermore, these commentaries could be used as a resource of other possible visualizations meeting a design consideration, *participatory and mash-up cultural data*.

Chapter 7

Conclusions

In summary, this dissertation is about the rhetoric and aesthetics of data visualization as a cultural interface. I was motivated to investigate this topic because 1) data visualization is an area where my interests in computational design and visual communication intersect, and 2) there does not yet exist a great deal of digital media studies or design research that discusses data visualization with a primary focus on rhetoric and aesthetics. The research methodology is characterized as "design research," a novel approach in digital media studies. Design research endeavors to construct knowledge of process, materials, and activities in design. In parallel with building a discipline, design research seeks solutions of research questions through creating artifacts. The critical approach of "research through design" is not only used to solve existing problems, but also to discover new problems surrounding us. With this methodology, this dissertation answers to the following three research questions: what are the influences of computation on the rhetoric and aesthetics of data visualization; how does data visualization function as a cultural interface for social and aesthetic expression; and how can design research as a methodology answer the previous two questions? Here I summarize the dissertation and reassure its contribution.

Rhetoric and aesthetics might not be small domains that one dissertation could embrace, but I attempted to identify how they were specifically manifested in computational visualization. Chapter 3 and 4 are devoted to rhetoric and aesthetics respectively and the following one integrates the two in one new term, "coded

visualization" and clarifies its unique characteristics and design criteria. For the discussion of rhetoric and aesthetics, I reviewed extensive literature spanning from classics to digital media studies, clarified neglected aspects by the current views from related fields, and argued the new possibilities driven by computation. I also found the connection between modern graphic design and computational visualization in terms of their social roles and the grounding ideas for aesthetics.

To build the theories for the rhetoric of computational visualization, I started with communication theories, visual rhetoric, and rhetoric in design. Next, based on the arguments of the rhetoric of non-digital visualization, I developed the rhetoric in digital environment by finding grounding theories from digital rhetoric, procedural rhetoric, digital media literacy, and participatory culture. Finally, I extensively discussed the influence of computation on the rhetoric of data visualization, covering users' involvement in conceiving data, experimental forms through digital production, rhetoric of interactivity, and the off-visualization engagement beyond a visualization medium.

For the aesthetic part, I approached in a slightly different way. I found there was no commonly shared comprehension of aesthetics among the related research areas. Aesthetics is either too confined only as beauty of surface, or overly philosophical or non-practical. Such problems motivated me to review the current views on aesthetics from Information Visualization researchers, early computer graphic scientists/artists, HCI theorists, and new media scholars. Synthesizing the missing or limited concepts and the learning from the review, I defined three new perspectives to view the aesthetics of data visualization—look and feel linking beauty and utility, aesthetic communication for trustworthiness, and situated aesthetics. Then I searched for the root of aesthetic forms of

data visualization from modern graphic design—the simple visual form is grounded in the modernists' rationalism of effective communication and remediated in the computation forms. I discussed the influence of computation on aesthetics with the following sub-topics—encyclopedic cultural contents, variable forms for modular data, aesthetics of pre-designed forms, interaction bridging functionality and storytelling, aesthetics of participatory culture, and direct visualization of cultural visualization.

As the readers of this thesis may have already thought that these two research foci—rhetoric and aesthetics—are not clearly distinctive or independent, while reading the chapters on them. Rather, the rhetoric and aesthetics, especially when driven by digital technology, affect each other. As discussed with a case of encyclopedic data, users generated data via social network services can create a new rhetoric and aesthetics. In another case, aesthetic communication assumes the rhetorical conversation between creators and audiences. I also discussed that the way that an interface is designed constructs a unique way of rhetoric. Thus, considering the reciprocal influences between rhetoric and aesthetics, I explicitly connected these two by coining a new term that could reflect their relationship.

Finally, in chapter 5, I coined "Coded Visualization" as a new kind of data visualization that could characterize my research focusing on the previously neglected aspects of visualization research in the previous research, and links rhetoric and aesthetics as a unified theme. I chose "code" because it had dual lexical meanings of computational generation (as we say in "write a code" or "source code") and semiotic functions (as author's intention is "encoded" in a medium and readers "decode" it), and the two can match to aesthetics and rhetoric respectively. I also characterized how coded

visualization is distinguished from other types of visualization and concluded that it could function as “cultural interface.” Cultural interface refers to the situation that computer is not used just a machine but provides audiences with a space where they can engage in the holistic process of making, using, and sharing cultural artifacts. In sum, coded visualization is a data-based interface whose processed data and aesthetic visual forms enable creators to encode their intentions for social expressions, and viewers or users to decode the hidden meanings with cultural references. To discuss coded visualization with a further step, I introduced the sequential design spaces of data visualization that included resources, content, form, interactivity, and context. Along these five spaces, I suggested a set of design criteria of coded visualization—participatory and mash-up cultural data, disagreement and conflict in contents, cultural references into computational forms, interaction for narratives and provocation, and proximate to current civic events and issues.

The final chapter discusses “research through design,’ in other words, the practices of design research. Based on the previously discussed theories, I designed a visualization-based system by applying the design criteria of coded visualization. Utilizing one of the most popular social network services and its open public data, *The Political Grid Project* targeted presidential elections in both the U.S. and South Korea in 2012. This site allows users to vote on the tweets by the two major presidential candidates with the two standards—“Do you agree with this tweet?” and “How important is it to you?”—on a numerical scale from -5 to 5. Using these voting data, I designed multiple visualizations that can be used for the users’ own investigation of the public’s opinion on these two candidates. Based on the analysis of users’ participation, I critiqued

the design criteria of coded visualization and suggested how to improve the site to more fully meet the criteria. Finally, the critique involves further design research agendas of coded visualization—more critical and provocative approach that even can challenge the objectivity and truth of visualization, interactivity of visualization beyond WIMP-like interface, and a unique form of on-site participation and off-site engagement that is specific to visualization media in digital environments.

At last, I summarize the contribution of this dissertation. First of all, the extensive literature review to induce the rhetoric and aesthetics of data visualization would be beneficial to digital media and design researchers who broadly seek the definitions of these two. More critically, throughout the theories and practices of coded visualization, this dissertation contributes to both design research and digital media studies.

Design as a professional practice has expanded its realm to encompass data visualization as graphic, information, and interaction designers produce data visualization. Graphic designers may have accumulated vernacular skills and tacit knowledge in their own community. However, practices of visualization with sizable data have been graphic designers' interest only in recent years, so that there is not yet a strong community-driven support for discussing the nature of this emerging sphere. Design researchers whose approach is alternative to traditional Human-Computer Interaction methodologies also use visualization as a form of prototyping, but they have not theoretically founded the grounds for visualization research. In regards with such troubled situations in both professional and academic design fields, this dissertation will contribute to design research on visualization that has growing concerns but a lack of foundations.

In digital media studies, there has been prominent research on rhetoric and aesthetics as a general theoretical contemplation, as well as a language to analyze specific media such as video games. However, the rhetoric and aesthetics focusing on data visualization have not received special attentions by digital media scholars. In fact, InfoVis and data journalism opened conversations, however researchers and practitioners in these domains still do not sufficiently discuss on the new affordances driven by digital technology, regarding these topics. In response to this deficiency, this dissertation lays the groundwork for the new discourses on visualization. It can be also useful for digital humanities that share similar attitudes with design research in terms of involving both interpreting and making. Coded visualization can be new tools for the interpretation of humanities text and the output of the making activities; the theory part of this dissertation provides new knowledge to read digital objects; the practice part involves building archives, designing analysis tools, and envisioning new digital methods.

Rhetoric and aesthetics are grand philosophical terms each of which has its own long disciplinary tradition. Digital media study has a relatively much shorter history, and Information Visualization (InfoVis) is an even younger domain. In this dissertation, I study this new digital media genre with the two historical but still important perspectives—rhetoric and aesthetics. I both expand the boundary of InfoVis research to include its historical roots from the modernists' era and specify my research focus as the influence of computation. My approaches include both constructing theories and researching through a design project, which are the two aspects of design research. With its unique approach to investigate the uncovered area of visualization research and design,

this dissertation contributes to digital media studies, design research, as well as Information Visualization.

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